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REORGANIZATION OF SCIENCE IN SECONDARY SCHOOLS

A REPORT OF THE COMMISSION ON THE REORGANIZATION OF SECONDARY EDUCATION, APPOINTED BY THE NATIONAL EDUCATION ASSOCIATION

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[1] Deceased, Sept. 4, 1917.

REPORTS OF THE COMMISSION ON THE REORGANIZATION OF SECONDARY EDUCATION.

The following reports of the commission have been issued as bulletins of the United States Bureau of Education, and may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the prices stated. Lower prices will be quoted for quantities. Remittance should be made in coin or money order. Other reports of the commission are in preparation.

1915, No. 23. The Teaching of Community Civics. 10 cents.
1916, No. 28. The Social Studies in Secondary Education. 10 cents.
1917, No. 2. Reorganization of English in Secondary Schools. 20 cents.
1917, No. 49. Music in Secondary Schools. 5 cents.
1917, No. 50. Physical Education in Secondary Schools. 5 cents.
1917, No. 51. Moral Values in Secondary Education. 5 cents.
1918, No. 19, Vocational Guidance in Secondary Schools. 5 cents.
1918, No. 35. Cardinal Principles of Secondary Education. 5 cents.
1919, No. 55. Business Education in Secondary Schools. 10 cents.
1920, No. 1. The Problem of Mathematics in Secondary Education. 5 cents.
1920, No. 26. Reorganization of Science in Secondary Schools. 10 cents.

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
BUREAU OF EDUCATION,
Washington, June 25, 1920.

SIR: I am transmitting herewith for publication as a bulletin of the Bureau of Education a manuscript on the Reorganization of Science in Secondary Schools, prepared by the science committee of the Commission on Reorganization of Secondary Education appointed by the National Education Association. Through an agreement with the National Education Association, the Bureau of Education is publishing all the reports of this commission. In the reconstruction to meet the new conditions following the war, much attention is being given to readjustment of science courses in high schools, and this bulletin should prove very helpful to many school officers and teachers.

Respectfully submitted.

P. P. CLAXTON,
Commissioner.

To the SECRETARY OF THE INTERIOR.

PREFACE.

The committee on science of the Commission on the Reorganization of Secondary Education has carried on its work by means of discussions, correspondence, and formulation of preliminary reports for over seven years. The discussion of preliminary reports by groups, committees, and at meetings of science teachers has revealed progressive work already under way and has led to the trial of preliminary recommendations. Some of the improvements that the committee sought to effect have already been adopted by many of the best schools. The full report herein presented, formulated through this procedure, incorporates practices that have proved most useful. It asks for only those features of reorganization that have been found to work well, or which by a fair amount of trial promise improvements. Further experiments with new courses in science, or with the readjustment of older courses, may make desirable and necessary a revision of the report before many years have passed.

The report embodies contributions and criticisms of more than 50 science teachers and administrative officers. It does not include every proposal, as many such proposals are not fully approved by others. Some members of subcommittees have been unable to send criticisms of the full report, but because of their previous important work on subcommittees their names are included in the list of members.

The report has been approved by the reviewing committee of the Commission on the Reorganization of Secondary Education. This approval does not commit every member of the reviewing committee individually to every statement and every implied educational doctrine. It does, however, mean essential agreement with the general recommendations.

Otis W. Caldwell,
Chairman Committee on Science.
Clarence D. Kingsley,
Chairman of the Commission.

REORGANIZATION OF SCIENCE IN SECONDARY SCHOOLS.

PART I.—THE AIMS, METHODS, AND ORGANIZATION OF SCIENCE AS A WHOLE IN SECONDARY EDUCATION.

I. GENERAL STATEMENT.

There is widespread recognition of the need for reorganizing science courses in secondary schools. Numerous encouraging efforts already have been made to redirect, enrich, and otherwise improve these courses. The variation of purposes for which sciences are taught, the increasing number of sciences offered, the development of intensive specialization within various sciences, the lack of sequence in the order in which they are frequently given, the wide variation in methods and content are striking evidences of the need for an approach to agreement. Only by comparison of the courses in many progressive schools can any tendency toward such uniformity be perceived. Steps should be taken also to prevent this increase in number and in specialization from diminishing the value of the instruction from the standpoint of the general needs of pupils and the needs of society.

Successful reorganization is made difficult by the narrow point of view of those persons who see in the movement an opportunity to advance the particular branch of science in which they are most interested and to demand for it a larger proportion of the pupil's time. More time is not a guaranty of increased efficiency. The more thoughtful teachers recognize that the values of science study will be increased if high-school science is planned as a whole and if the separate courses are made to follow fundamental principles of sequence. The progressive development of the pupil is essential. Moreover, the science course in any high-school year should be so organized as to constitute the best training for that period, regardless of any further science courses that the pupil may take.

The task of reorganization would be met only partially and incompletely if it attempted no more than an organization of coherent courses. Each science course needs such redefining as to purpose, and such rearranging of materials, as will bring it into harmony with valid principles. The proposed organization of subject matter is based upon:

(*a*) Numerous studies of the tendencies in science teaching in the country at large, and particularly in secondary schools in which experimental work upon reorganization has been undertaken.

(*b*) The experience and judgment of science teachers who have studied the modern needs of science teaching.

(*c*) The judgment of supervising officers and professors of education as expressed in their writings bearing upon science teaching and in their criticisms of the manuscript of this report.

Part I of this report contains three main divisions:

I. The general aims and purposes of secondary science instruction.

II. General principles governing the selection of material and its presentation.

III. Science sequences recommended for various conditions.

Part II of the report presents the principal courses in science treated separately.

II. GENERAL AIMS AND PURPOSES.

The general aims and purposes of science teaching are here stated first with reference to the main objectives of education, and secondly, with reference to the specific knowledge, habits, powers, interests, and ideals that should be developed.

A. *Contribution to educational objectives.*—The Commission on the Reorganization of Secondary Education in its report entitled "Cardinal Principles of Secondary Education" (Bul. No. 35, 1918, U. S. Bu. of Edu.) has set forth seven main objectives of education upon which work in the secondary school should be focused. These objectives are derived from the point of view of the commission, namely, that:

> It is the firm belief of this commission that secondary education in the United States must aim at nothing less than complete and worthy living for all youth, and that therefore the objectives described herein must find place in the education of every boy and girl.

Science instruction is especially valuable in the realization of six of these objectives, namely, health, worthy home membership, vocation, citizenship, the worthy use of leisure, and ethical character.

(1) Health.—It is important that those who are ill may be cured, but it is much more important that people be so taught that they may not become ill. The control and elimination of disease, the provision of adequate hospital facilities and medical inspection, the maintenance of the public health, all necessitate widely disseminated knowledge and practice of the basic principles of personal hygiene and public sanitation. It is the duty of the secondary schools to provide such instruction for all pupils. This purpose finds realiza-

tion chiefly through science and civics. Therefore, health topics should be included in the science taught in the junior high school, and in at least the first two years of the four-year high school.

(2) Worthy home membership.—Science touches the efficiency of the home and of life within the home at every angle. General science, biology, physiology, physics, chemistry, all have definite services to render toward the proper organization, use, and support of home life. A great vitalizing force for science instruction can be found in the relation of these courses to intelligent homemaking, management, and enjoyment. It is a serious criticism of science teaching in the past that these fundamental relationships have been so largely overlooked. These relationships apply not only to those who have the care of the home and of the children within it, but also to such other members of the family as may be called upon to make repairs to the heating and ventilating system, to adjust the electrical appliances, or to perform any of the many services that make for an effective home. Science has devised many conveniences that make the modern home comfortable and attractive, and science knowledge is required for their full appreciation and most intelligent use. These activities should be definitely related to better ideals regarding modern home life.

(3) Vocation.—Science instruction should contribute both to vocational guidance and to a broad preparation for vocation.

In the field of vocational guidance such instruction should make many valuable contributions to a more intelligent understanding of the world's work and such an understanding should be so presented as to be of direct assistance in the wise selection of a vocation. Such knowledge should also impress students selecting certain vocations with the importance of making thorough and adequate preparation for their life work.

In the field of vocational preparation, courses in shop physics, applied electricity, physics of the home, industrial and household chemistry, applied biological sciences, physiology, and hygiene will be of value to many students if properly adapted to their needs. Often a knowledge of the underlying principles increases the worker's enjoyment, helping him to think intelligently about and understand the processes with which he deals. Moreover, such knowledge and the interest aroused thereby may result in improving the work itself, and may result in inventions for the improvement of the work of others.

(4) Citizenship.—The members of a democratic society need a far greater appreciation of the part which scientifically trained men and women should perform in advancing the welfare of society. Science teaching should therefore be especially valuable in the field of

citizenship because of the increased respect which the citizen should obtain for the expert, and should increase his ability to select experts wisely for positions requiring expert knowledge. At the same time it should afford the basis for an intelligent evaluation of the services rendered by such experts.

Furthermore, the study of science should give a more intelligent appreciation of the services rendered to society by those who are engaged in vocations of a scientific nature and occupations based upon applications of science. Such appreciation of the services rendered should lead to greater respect for the worker who renders the service.

(5) Use of leisure time.—Science opens the door to many useful and pleasurable avocations. Photography may be taken up by many, but most intelligently by one who understands something of the nature of light, the action of lenses, the chemical changes involved in exposing, developing, and fixing plate and print. In the city and in the country, at the seashore, mountains, and elsewhere, nature is prodigal of her store of wonders. If the natural interest in these things has been developed and deepened by elementary courses in biology, botany, or zoology, not only is there added pleasure and enjoyment, but the door has been opened to wider interests, and to a rapidly growing fund of valuable literature regarding science. The marvelous adaptations of plants to their environment, the march of plant progressions, the sharp competitions among the forms of animal and plant life, the history of the remote past recorded in the rocks, are topics which mean much to one whose eyes have been opened by science instruction. To have avocational value, science courses should employ methods that can be used after school days. Trips to industrial plants to study raw materials, processes, and finished products, and visits to museums, are means of developing lifelong sources of enjoyment.

(6) Ethical character.—Science study should assist in the development of ethical character by establishing a more adequate conception of truth and a confidence in the laws of cause and effect. Science, along with other studies that exalt truth and establish laws, should help develop sane and sound methods of thinking upon the problems of life.

B. Specific values of science study.—(1) The development of interests, habits, and abilities.—Each pupil of secondary school age should develop many and varied interests in the fields of science. In times past these interests came to a great extent from experiences in home life, particularly on the farm and in the village, but as life has become increasingly complex and specialized it devolves more and more upon the school to supply the opportunities for actual

contact with materials that have real significance in the life of man, contacts that result in keen interests, appreciation, and power. To be of the maximum effect the experiences should be markedly different from those that are vicariously furnished by books, diagrams, and symbolic materials, such as make up the content of many subjects of study.

(2) Teaching useful methods of solving problems.—The new science should also develop direct, effective, and satisfying methods of solving problems. If these methods are to be of wide use outside the school, they must be formed through and firmly associated with the kinds of experiences that arise in common needs. Real situations and good methods consciously and constantly applied with satisfying results are necessary for this purpose.

(3) Stimulation.—Good science instruction should stimulate the pupil to more direct and purposeful activities. It should lead to a higher appreciation of the pleasure and profit to be obtained by the exercise of his own abilities. The value of science instruction for this purpose depends upon the character of the material used, the appeal made to divergent interests, and the connection shown with common questions of everyday life.

(4) Information values.—Science study should give the pupil control of a large body of facts and principles of significance in the home, school, and community. It should build up an intelligent understanding of the conditions, institutions, demands, and opportunities of modern life. The value is not only in the facts and principles but also in the measure to which they represent points of view, deepened and intensified powers of insight, methods of procedure, and points of departure for new attempts for further study.

(5) Cultural and æsthetic values.—The dualism that would classify subjects as cultural or noncultural, as humanistic or scientific, as æsthetic or materialistic, with an implication of the inferiority of the latter to the former, is rapidly dying out. All subjects are cultural in the degree to which they develop wider appreciations of the worth while. Science study properly conducted develops an appreciation of the inner meanings and connections of things, an appreciation of the service of science to the life and civilization of our time, an appreciation of the slow, painstaking efforts and tremendous toil with which scientific progress has been accomplished, and an appreciation of the privileges, duties, and responsibilities that living in this age of science involves.

So, also, all subjects are æsthetic in the degree to which they open the eyes to the perception of new beauty and increase the power to understand and enjoy.

III. GENERAL PRINCIPLES GOVERNING THE SELECTION OF MATERIAL AND ITS PRESENTATION.

A. *Point of view in organizing work.*—Science for high-school students has been too largely organized for the purpose of giving information and training in each of the sciences, the material being arranged in accordance with the logical sequence recognized by special students of that science. The theory sought justification in the claim that the secondary course is introductory to more advanced study, and as such should introduce the student to each of the leading phases of the subject; furthermore, since special students in each of the sciences have discovered or developed systems of organizing those materials, it was held that the beginner should be given the fundamentals of this system of organization.

Neither in common life activities nor in research is the artificial stratification of the sciences maintained in solving problems. Not only is science organized and tested knowledge which in the process of testing has become highly classified, but true science includes the *process* of organizing, testing, and determining the effectiveness of knowledge. The common method of science teaching too often has been that of presenting the so-called essentials with their definitions and classifications and of subordinating or omitting the commonplace manifestations of science in home, community, civic, and industrial situations which make it most easily possible for the learner to practice science.

Introductory science attempts to reverse the traditional method of teaching. It attempts to start with questions of immediate interest to the pupil, ideas which are significant to him by reason of his own experience and which concern his own life to such an extent that he perceives or is easily led to perceive their worthwhileness. With developing experience as a background and interest as a spur, the pupil turns his energies to the solution of a problem which really engages him, regardless of the particular science in which his problem lies.

The most radical teachers of science in secondary schools assert that there is little or no value in recognizing the specialist's system or organization when teaching science in the secondary school; instead, they would discard all organization of this kind. These teachers would adopt the so-called project method of organization for all science in secondary schools.

The less radical of the progressive teachers would adopt unified topics as the basis of organization of introductory science courses, but would retain the differentiated special science courses for the upper high-school years.

This report is based upon the second point of view, that is, the point of view of the less radical of the progressive teachers.

(1) Organization.—Selection and presentation of science work should rest on the following:

a. Self activity is a law of growth.

b. Interest secures attention and makes self activity possible.

c. Interest, to be sustained, must rest on the perception of the worthwhileness to the individual of the purpose sought.

d. A usable question, problem, project, or topic involves a purpose, the immediate or future worthwhileness of which is recognized by the individual and by the class.

(*a*) Centralizing topics.—Questions, problems, and projects are usually related to some centralizing topic, which topic may then constitute a teaching unit. Projects may involve any or all of the following kinds of work: Construction, experiments and the interpretation of experimental data, consultation of reference and textbooks, class discussion, group conferences, individual reports and field trips.

(*b*) Project defined.—A project is any projected or proposed activity or experience which an individual purposes to enter upon or carry through to the end. It may be to make an electric motor, to understand how a motor works or why it will not work, to repair a broken motor, or to find out what are the origin and nature of any one of the materials of which a motor is constructed; it may be to find out about the structure and proper manipulation of an automobile or of a bicycle; it may be to rid a community of mosquitoes or houseflies, or to find out how some former generation of men dealt or failed to deal with any particular problem of health and disease; it may be to find out how to prepare the meals for a group of guests throughout a summer's vacation. The project may involve any specific thing which the pupil purposes to do, whether this thing is a small piece of work involving a few minutes' effort, or a prolonged piece of work lasting for weeks, the unit depending upon the conception of the piece of work which it is purposed to accomplish.

(*c*) Relation of project to topics.—In teaching science, however, teachers must consider what pupils do both before and after. Hence teachers need to see the units of work in terms of the aggregates into which these units may be organized. All of a given group of units likely to arise in relation to one line of consideration are readily related by pupils and teachers to one another under one topic. Some of the units might properly arise under any of several topics, and are of course to be grouped so that their purposeful relations are best recognized. A coherence, significant to the pupil, should be sought.

On account of the difficulties and disagreements which arise when terms rather than point of view are emphasized, the following outline of subjects avoids as far as possible the use of controversial terms. It endeavors instead to use expressions and to outline purposes, content, and procedure which show the point of view.

(2) The natural way of working.—This plan of presenting introductory science possesses the advantage of building on interest and commonplace experience, thus securing more self-activity and self-educative effort. The problems and projects are unified on the basis of individual experience, class discussions, laboratory work, and the study of textbook and reference material. This plan involves all the elements of a complete cycle of thinking: (1) Perception of a need resulting in a question to be answered or a problem to be solved; (2) the presentation of possible explanations or hypotheses; (3) trial and discussion of possible explanations; (4) adequate verification of the most probable explanations; (5) the relation of the particular study to other phases of the topic to the end that a usable and orderly arrangement of new attainments may result. This is the natural way of working. It is the way of adults, of research students, of business men and women, of children themselves outside of school when left to themselves. This procedure gives training in ways of working which the pupil must use outside of school both during and following his school days.

(3) Dangers to be avoided.—The difficulty of shifting from the accustomed method of teaching, the inexperience of teachers, the failure to find or select topics and problems of the proper sort, while not inherent in the method, are none the less real difficulties.

There is great danger that interest of only a superficial sort will be aroused, and that the class work will degenerate into mere entertainment, amusing or curious, but not essentially educative. The failure to secure sustained and progressive interest means failure to secure progress. Topics chosen must be so treated as to secure clarifying generalizations and logical organization. Some of the generalizations formerly insisted upon will be seen to have little practical significance, and consequently will be omitted. In the present experimental status of this method of selection teachers must guard carefully against the tendency to institute a series of unrelated activities, so that generalization and coherent arrangement are lost. Organization should be achieved as a result of the pupil's work, and not forced upon him as the point of departure. A generalization is valuable only when it represents a unifying idea, by which known facts or processes are related and from which new facts may be surveyed as a step toward a still more complete organization. If these principles are carefully followed there need be no danger of an "easy" or "soft" education, which no science teacher desires. On the con-

trary, it should result in a more active and more demanding kind of education because of increased significance and thereby increased recognition of need for real knowledge.

(4) Considerations determining the choice of topics.—These should be chosen on the basis of their fundamental relation to life as indicated by the following:

(*a*) They should be based on common experience and the needs organically related to them.

(*b*) They should relate to local industries, community and school activities, and the life of the home. They should extend from these to larger considerations.

(*c*) They should be graded so as to be hard enough to call for the pupil's best efforts, and should become increasingly difficult as the pupil develops his power of attack through experience.

(*d*) All pieces of work should be unified under central topics in progressive order, so that whenever possible the results of one piece of work may find use in another. The problem of organization should be made a part of the pupil's work.

(5) The advanced courses in science.—The method of organization outlined above has been successfully tried in the science courses of junior high schools and in the first two years of four-year high schools. In senior high schools and in the upper years of four-year high schools this method of organization has not been extensively tried. With more mature students and with the gain of one or two years of substantial work in science, organized as suggested above, these later courses may properly cover an amount and rigor of study considerably in excess of that included in former courses. With this background, the commonly accepted plan of organization in the different special sciences may continue to be best, though further readjustment may later be advisable. These science courses need to be reorganized so as to use and not unnecessarily duplicate the materials and methods of the introductory science courses.

B. Laboratory procedure.—The fact that laboratory work in general has not accomplished the results expected indicates the need for reorganization of the method and content of laboratory work. A few common causes of disappointment are:

(1) Experiments are too frequently devised to check up and prove generalizations or laws the truth of which the pupil already perceives.

(2) Experiments often repeat work described in the text in such a way that the outcome is uninteresting and of little value.

(3) The data collected in many experiments are an end in themselves. There is no further use for them, and hence they have no

significance for the pupil. Such "busy work" serves no worthy purpose.

(4) Many experiments are too minutely quantitative and call for refinements beyond the need or appreciation of secondary school pupils.

Too frequently the laboratory and classroom, sometimes improperly called "lecture room," are separate not only physically but intellectually.

The laboratory should be a place where the pupil puts questions to nature, observes accurately, and deduces conclusions logically, not a place where directions are followed blindly and meaningless results obtained. The value of individual laboratory work has been seriously injured by requiring each pupil to do exactly the same experiment as every other pupil and do it in as nearly the same time and same way as possible. The spirit of the project method should vitalize the experimental work. There will always be some pupils who should modify the work to meet their special needs or interests. Such differentiation should be encouraged and lists of alternative work should be available to utilize individual interests and inclinations.

Improvement of laboratory practice will result in less cumbersome forms of note taking and of notebook making. The experiment is not designed for the sake of a notebook record. A summary of results which can be used in interpreting the work done should be made and pupils should be allowed much freedom in the precise manner in which the record is made. They should record important and significant facts, and the record should be clear and complete. That is, the laboratory is a "work place," and records should be simple and direct accounts of the real and vital work that has been done.

C. *Class-room procedure.*—The adoption of the problem-project-topic method of science teaching will lead to a considerable change in the purpose and use of the recitation period. The "hearing of lessons," memoriter repetition of facts and principles gleaned from the textbook, the more or less discontinuous dialogues between teacher and individual pupil should give place to a real class discussion in which all take an active part in contributing, organizing, and using the information dealt with. In such discussions the teacher serves to direct, stimulate, and advise. There should be a maximum opportunity for self-expression in the immediate problem.

In the recitation period the skillful teacher will develop and arouse interest, furnish the necessary background, and direct the class in its search for answers to a vital problem. In the development of such work the demonstration experiment plays an important part. Such experiments need not be spectacular and sensational, but the

unexpected may well be utilized to arouse interest and raise questions that the teacher wants raised as fundamental to the initiation of a class problem. In the overemphasis on individual laboratory work, the value of demonstration experiments has been minimized. Such demonstrations, besides being interest provoking, have many of the merits of individual efforts without the confusion due to poor manipulation or the failure to observe the most important aspects of the experiment. These may serve the class as examples of the proper way of working, of manipulating apparatus, of noting results, and of drawing inferences. Pupils should be encouraged to assist in performing demonstration experiments.

The recitation is often the center from which other class activities radiate. It focuses the work done in the laboratory, at home, in the library, and in excursions. To it all contributions are brought and offered for the consideration of the entire class. The need of text books is constant but usually no single text book can serve for all the needs of an actively working class. A better plan often is to provide several copies of the more important texts and a number of reference books to which assignment may be made. It is extremely important that such assignments should be definite and clear to the pupil. Few things are more discouraging to the pupil or more destructive of his interest than to be given hazy assignments, and to feel that neither he nor the teacher knows exactly what is expected.

It is not to be supposed that all pupils will be equally interested in a given topic, but if the interest of the majority can not be aroused the validity of the topic should be examined. On the other hand individuals who have little interest or in whom no interest can be aroused, or those who have a very special interest, may often be encouraged to pursue individual problems of their own and to report their work to the whole class. Such problems encourage initiative and individual responsibility. The results of such work should be interesting to the class as a whole, and reports to the class by all pupils should be a regular part of recitation work. All pupils should be encouraged to undertake some individual problems of their own choosing.

D. *Cooperation between pupil and teacher, school, home, and community.*—At many points in the above discussion the importance of cooperation between pupils and teacher has been suggested. It is vital to success in teaching, and especially in teaching by the problem method. How true it is that in most classes we find the teacher alone active, the class passive, the teacher dominant and aggressive, the class repressed, and attentive in only a receptive not in a cooperative sense. The responsibility for this rests squarely upon the teachers whose methods have resulted in this type of practice.

Although implied in several preceding statements, the need of home and community cooperation with the science work of the school should be specifically mentioned. Indeed, the kind of science teaching for which this whole report argues can not be developed except through constant use of the manifestations of science in the work in which men and women are regularly engaged. It will appear later in the outlines of courses that science in secondary schools finds its proper basis in personal, home, and community life and needs. Therefore when teachers and pupils ask to visit a farm, orchard, a shop, a flour mill, saw mill, or manufacturing plant, the business men concerned should be informed of the ways in which these visits contribute to the courses in science, to the end that they may understand that they are helping in the work of education. Also, it may properly be the function of the teacher and class to collect desired information or conduct experiments which are related to the business concerned, and are desired by those engaged in this business.

Any device, plan, or method that will build up helpful cooperation between the home, school, and the community should be encouraged. Among the topics that call for just this kind of cooperation are the following: Home gardens; community extermination of flies and mosquitoes; insects injurious to shade trees and agriculture; protection and feeding of useful birds; care of the water supply; protection from sewage contamination; community cleanliness; development and care of public parks; health in local industrial plants; and any other topics which inhere in or arise from the elementary study of general science, biology, chemistry, and physics.

IV. SCIENCE SEQUENCES RECOMMENDED FOR VARIOUS CONDITIONS.

The science sequences should vary with the type and environment of the schools. Each year's work should be so outlined as to give the best training without reference to whether the pupils take later courses in science. Many schools will need to make readjustments of a recommended sequence, so that it may best serve the school's particular constituency. The committee has outlined sequences for the following types of high schools:

A. The junior-senior high school.

B. The large four-year comprehensive high school with adequate teaching staff and equipment, usually enrolling over 500 pupils.

C. The four-year high school of medium size, usually enrolling from 200 to 500 pupils.

D. The small high school of not more than 200 pupils.

A. *The junior-senior high school.*—Seventh or eighth year, five periods a week; or both years with three periods a week in each year—General science, including hygiene.

Ninth year—Biological science, including hygiene; courses may consist of general biology, botany, or zoology.

Tenth year, eleventh year, twelfth year—Differentiated elective courses in sufficient number to meet special needs and interests, as follows:

(*a*) Chemistry—General chemistry, and chemistry specialized for various curriculum needs, such as household chemistry, industrial chemistry, etc.

(*b*) Physics—General physics; and physics specialized for various curriculum needs, such as physics of the home, industrial physics, etc.

(*c*) General geography, or physiography.

(*d*) Advanced biological sciences.

B. *The large comprehensive four-year high school.*—The conditions usually prevailing in these schools make possible a wide differentiation of science courses, since there are likely to be enough pupils with special interests to constitute adequate classes in differentiated science courses. In such four-year high schools the following plan is recommended:

First year.—General science, including hygiene.

Second year—Biological science, including hygiene; courses may consist of general biology, botany, or zoology.

Third and fourth year—Differentiated elective courses to meet special needs and interests as follows:

(*a*) Chemistry—General chemistry, and chemistry specialized for various curriculum needs, such as household chemistry, industrial chemistry, etc.

(*b*) Physics—General physics; and physics specialized for various curriculum needs, such as physics of the home, industrial physics, etc.

(*c*) General geography, or physiography.

(*d*) Advanced biological sciences.

C. *Four-year high school of medium size.*—First year—General science, including hygiene.

Second year.—Biological science, including hygiene; courses may consist of general biology, botany, or zoology.

Third year.—Chemistry, with emphasis on the home, farm, and industries.

Fourth year.—Physics, with emphasis on the home, farm, and industries, general geography or physiography, or advanced biological sciences.

D. *Small high school.*—First year.—General science, including hygiene.

Second year.—Biological science, including hygiene; courses may consist of general biology, botany, or zoology.

Third and fourth years.—Elective chemistry and physics.—In the small high school it is desirable to alternate the courses in chemistry and physics in successive years.

NOTE.—This report does not deal directly with agriculture and home economics, since there are separate committees dealing with those subjects and the reports upon those subjects constitute separate publications. The omission of a special report upon physiography and general geography from later pages of this report does not indicate that the committee would omit these subjects from secondary schools. The special committee on these subjects has not formulated a report. It is understood that a committee of the National Council of Geography Teachers will probably prepare a report upon geography and physiography in the high school.

PART II.—THE PRINCIPAL COURSES IN SCIENCE.

I. GENERAL SCIENCE.

This introductory course in science is not a substitute for any one of the special sciences, but should provide a basis for discovery of interest in special sciences and of vocational opportunity. It should prove to be the best training for any pupils who can take only one course in science in high schools.

A. *Selection and organization of subject matter.*—The subject matter of general science should be selected to a large extent from the environment. It will therefore vary greatly in different communities. The science involved in normal human activities, and especially the science involved in the reconstruction period after the war, presents many real problems which must be met more intelligently than formerly if there is to be the needed increase in effectiveness of the service which individuals and groups are expected to give. Science is universal and constant in the life of our citizens, and hence to be useful to all pupils general science must accept the science of common things as its legitimate field. The science of common use and that of the classroom should be the same. General science should use any phase of any special science which is pertinent in the citizen's interpretation of a worth while problem.

The particular units of study should be those that truly interest the pupils. Interest not only secures productive attention but is an evidence of attention. To be substantial educationally, interest must rest upon a sense of value, an evident worthwhileness in the topics considered.

No topic should be selected which is meagre in content or lacking in significant problems. The range of material which can be used is in reality limited only by the capacity, experiences, and needs of the pupils. The materials should be concrete and capable of leading to many avenues of new and untried experiences.

In *organizing* this material the topic should be the large unit to which many specific pieces of work are related. For example, a general topic such as *fire* may be selected. Many specific pieces of work will arise—one of practical value being "The Hot Air Furnace," or any other definite system of heating. The problems for solution under this topic will be varied and many, as: What causes the air to circulate? How does it circulate? How should pipe valves be arranged to cause equal circulation in all rooms of a house?

To answer these questions many experiments and demonstrations must be made. Again, in the study of the local water system, determine the uses now made of water and the benefits and dangers of the system, construct models of mechanical devices used in the system for securing and delivering water and for disposal of wastes, etc. The following list of subtopics will suggest the content of the whole topic: The common uses of water; local dangers of contamination; sources of supply in use and possibilities for extension of system; relation to public health with typhoid as an illustration; sewage, its uses and dangers.

B. *Methods.*—The foregoing discussion of selection and organization suggests the point of view in presentation. Topics should be large units. At the outset the topic should be viewed briefly as a whole for the sake of perspective. Such a general view gives a concrete and significant basis to which there should be constant return and to which further and more detailed and more exact studies should be constantly related.

A combination of class presentations of out-of-school experiences, of individual laboratory work, and of teacher-and-pupil demonstrations is desirable. Simple materials should constitute most of the laboratory apparatus. The desk demonstration by teacher or pupils is excellent as a means of presenting an experiment for observation and discussion so that the attention of all may be definitely directed to the question in mind. Pupil demonstrations and individual laboratory work also should be used, since they give individual opportunity to handle apparatus and opportunities for active participation by each pupil. There is no objection to the same problem being solved by the whole class as individuals or as groups, provided that the class as a whole feels the importance of the work; but care must be taken when assigning the same task to all to see that the work does not become meaningless for some. Sixty-minute laboratory periods are generally better than longer periods for introductory science courses. An abundance of textbook and other reading matter should be available.

No text in general science can or should supply answers to all inquiries. The textbook should be used as a reading and reference book, and other sources for reading should be extensively used, such as magazine articles which deal with current use of science. References should be specific for children of the age of general science pupils, since they will gladly do much reading if they know just what to read.

Bulletins of available current reading matter prepared by teachers and pupils are an aid in reference work, and are stimulating to teacher and pupil.

Excursions, well directed and with a purposeful plan, are of great value. Excursions should always be definitely planned, carried out as serious exercises, and the results used in later work. Pupils and teacher should look upon excursions as a regular part of the serious work of the course.

C. *Sample topics.*—It is not desirable that there should be a syllabus to which teachers shall adhere, but instead enough topics should be presented as illustrations to indicate clearly the kinds of materials recommended. The topics here presented are based upon those actually used in a high school in a city of approximately 150,000 inhabitants. In other schools—for example, a school in a strictly agricultural community—many changes would naturally be made. In the city from which this outline is selected the course varies from year to year according to the topics on which emphasis is needed.

Topic 1. *Combustion.*—Why our homes must be heated at times and cooled at other times; sources of heat; kinds of fuel; making a bonfire; list of questions about bonfires; why the fire burns; lesson on elementary chemistry—elements and compounds; what becomes of wood when burned; oxidation; why stones are not used for fuel; heat produced by oxidation; making a thermometer; effects of heating iron, water, wood; slow heating of water; thermostat; how heat travels; ways for heating a home; how the science room is heated; study of a chimney; what smoke is; how common illuminating gas is made; properties of illuminating gas; how gas is made in this city; study of candle flames; study of Bunsen burner and its use; carbon dioxid, how produced; body fires—relation to physiology; control of fires; losses from fires and how to prevent them; what is a fire insurance company; does the insurance rate in this city indicate that fires are more common here than elsewhere?

Topic 2. *Water.*—Three forms of water; how used in home and school; changes from one to another; relation of heat to these changes; changing water to steam; evaporation; ice machines; changing vapor to water; condensation; dew; rain; frost; snow; distillation and applications; transpiration; running water; where from, where going, and why; rate of flow; erosion and its effects; erosion and forests; erosion and crops; erosion and farm values; influence of bodies of water on climate; fruit belt about large bodies of water; composition of water; analysis and synthesis; water in relation to health problems; distribution of bacteria; typhoid as illustration; water supply and sewage disposal in this city; source of water; impurities; filtration; water system; sewers; various methods for disposal; the one used in this city; industrial uses of water; water a solvent; relation to household use; relation of this to plant and animal life;

uses of water in industries; relation of water to geographic location of industries; water pressure as used in machines.

Topic 3. *The air and the weather.*—Does air occupy space? Why can you kick a football farther when it is inflated than when empty? Does air have weight? determination of weight of air in classroom; air pressure; common pump; meaning of pressure barometer; biography of Galileo and Torricella; story of making first barometer; distinction between weight and pressure; moisture in air; effect on weight of air; relation of temperature and atmosphere to moisture in air; dew point; frost, rain; dew; air pressure and winds: highs and lows; weather map; what it is designed to show; how forecasts are made; rainfall map; importance of rainfall; composition of air; impurities in the air.

Topic 4. *Light and its benefits.*—Why and how things are visible; intensity of illumination; measuring the light; reflection; refraction; color, photography; artificial lighting; benefits of light; sunlight and health.

Topic 5. *Work and energy.*—Work by running water; machines; mills run by water power; pumps run by water power; elevators run by water power; gasoline engine; biography of James Watt; Mechanical energy and heat.

Topic 6. *Magnetism and electricity.*—Frictional electricity; a magnet; earth magnetism, the compass; a battery, kinds of batteries; current electricity, heating effects, household appliances; chemical effects of electricity; electroplating; magnet effects, electro magnets, electric bell, telegraph, motors; induced currents, dynamo, telephone.

Topic 7. *Nature's balance of life.*—Meaning of possible overproduction as shown by calculations of possible numbers of new individuals; rabbit; fox; wolf; potatoes; limiting conditions; why some forms stay and others do not; biography of Charles Darwin; artificial selection; good seed and poor seed and the results; germination; soil as source of plant food; subtraction and addition of soil elements; why a plant needs water; how water rises through the soil; how liquid goes from cell to cell; food factories for all living things; leaf structure; light and chlorophyll; products and by-products; air for plants; public parks and city trees; birds and their food in relation to balance of life; migration in relation to balance of life; protection; plant reproduction; structure of flower; seed distribution of dispersal; seed of burdock in relation to balance of life; the problems of successful living.

NOTE.—Most teachers of general science have found it wise to use several topics in addition to those included in the above list, the above being merely suggestive of the types of topics recommended.

II. BIOLOGICAL SCIENCES.

A. *Place of biological sciences.*—The biological sciences now taught in high schools are general biology, botany, zoology, physiology, hygiene, and sanitation. These subjects do not represent the full extent of differentiation, since there is a tendency toward further specialization within some of these subjects. Investigation shows also that in some four-year high schools any one of these subjects may be elected by any pupil in any semester. The length of time given to a biological course ranges from one-third of a year in some schools to two years in other schools. An investigation of a large number of four-year high schools in a wide range of localities indicates a distinct tendency toward a sequence of courses consisting of a general science course offered in the first year of the four-year high school followed by the biological subjects in the tenth grade. In a few States there is a tendency to have biology given as the science of the first year of the four-year high school. In junior-senior high schools the tendency is to require a course in general science followed by a course in general biology in the junior high school, with opportunity for the election of special courses in botany and zoology as well as other sciences in the senior high school. It is recommended that in four-year high schools a course in biology be given in the second year and that in the junior-senior high schools this subject be given in the last year of the junior high school, and that in large schools other biological sciences be offered as electives in later years of the high school.

B. *Changes in the point of view in biological teaching.*—When biology was introduced into the secondary school, the subject was taught by men and women trained almost wholly in college courses in morphology and classification; and in consequence a diluted type of college course was almost inevitable in the high school. Much of the laboratory material consisted of preserved specimens of plants and animals. Microscopical work of too difficult a type was insisted upon. Herbaria of dried specimens cluttered home and school.

In recent years increasing emphasis has been placed on the study of living organisms. Physiological experiments and ecological studies have been introduced. But still the type of topic selected for study is more or less that which appeals to the adult mind rather than to the mind of the adolescent. The material used was often remote from the every day experience of the students, and biological studies still failed to function as largely as had been hoped.

When teachers began to present biology in its relation to human welfare, a new and vital interest in the subject was awakened, and in many schools biology has become deservedly popular. It is evident that further progress in the pedagogy of the subject should be

made along the line of organization of courses in biology which relate to various aspects of human welfare.

C. *Aims.*—Biological sciences, in common with the other sciences in secondary schools, should contribute to the educational objectives stated on page 12—health, worthy home membership, vocation, citizenship, the worthy use of leisure, and ethical character. In particular, biological sciences should have the following specific aims:

(1) The World War has emphasized health as a basic end of education. Since much of biology deals directly with problems of health, the course in biology must accept efficient health instruction as one of its chief and specific ends.

(2) The biological sciences should develop the pupil's purposeful interest in the life of the environment by giving a first-hand acquaintance with plant and animal neighbors.

(3) They should emphasize some of the most important applications of biological science to human activities and to general and individual human welfare, and especially should familiarize the pupil with the structure and functions of his own body, to the end that he may know why he must live healthfully in order to live happily and usefully.

(4) They should train the pupil to observe life phenomena accurately and to form logical conclusions through the solution of problems and through projects essential to the productive work of agriculture, gardening, etc.

(5) They should enrich the life of the pupil through the æsthetic appeal of plants and animals studied, to the end that he may appreciate and enjoy nature.

(6) They should demonstrate to the pupil the value of intensive study of biological science as a means through which scientific progress is attained. In view of what science has meant to our present day civilization and in view of the measure in which the methods and results of scientific investigation are to-day reflected in intelligent thought and intelligent action, the need of the life sciences in the education of modern citizens can not be ignored.

D. *Sequence and continuity.*—The sequences recommended in Part I of this report provide for (1) one year of general biology for all pupils in the second year of four-year high schools and in the last year of junior high schools, (2) the election of courses in botany, zoology, and physiology in the third or fourth year of four-year high schools and in any year in senior high schools. The intricate and detailed study of those abstractions that are more difficult for the pupil to understand and appreciate will thus be left for the special biological courses in the later high-school years, and may then be elected by those who have special interests and needs.

The committee commends elasticity in the content. A one-year course in general biology in the ninth or tenth grade, using both plant and animal materials, often admits of a more economical as well as a more effective expenditure of time and materials than can be secured by the plan of grouping living materials into separate half-year courses in botany and zoology. However, the course in biology may well be varied so as to suit local conditions and to relate it to other courses. In many of the best high schools a choice of the full year of botany, zoology, or human physiology, instead of general biology in the tenth grade, has been found highly satisfactory.

This committee believes that coherence and unity of subject matter are important in any science course, elementary or advanced. Only through such sequence and unity does a child or adult gain a clear vision of the significant principles of a science. This does not sacrifice interrelation between the sciences or the use of the project method. On the contrary, through the unity of the course the pursuit of any one science intensively should result in a general insight into all science. On the other hand, study of isolated phenomena may result in a mass of informational material and a sacrifice of the very ideals that science endeavors to inculcate.

E. *Content of a general biology course.*—The committee believes that a course in biology in the ninth or tenth year should be what the name implies—a study of living things. The central ideas should be:

1. The way in which each organism maintains its own life and the life of the species.

2. The interrelations between different organisms and groups of organisms.

3. The constant dependence and interrelations of living things with the physical world about them.

4. The power of man to control the habits and relationships of plants and animals to serve his own ends.

The starting point is not important if only topics of compelling interest to the child are chosen. The topic may be such as "The war between organisms which is being waged in a vacant lot." Consideration should be given to such questions as the number of species of plants found there; the ones which have the greater area; how they secured their hold on the region and whether they can continue to hold it; what will become of the plants as fall approaches; the relation of these organisms to those in neighboring lots; parasitic plants and animals and other dependent forms. Another introductory topic may be "A balanced aquarium," illustrating the carbon and nitrogen cycles in nature in lakes, rivers, and oceans. Still another is the topic of overproduction, as illustrated in the possible

rate of reproduction by corn or the house fly. If corn is chosen, the pupils may be asked to calculate how long it would take one ear to produce corn enough to plant his whole State, or if the fly is chosen to calculate the number of offspring in one season and the space these would occupy. The home garden provides another excellent initial topic for the biology course.

The topic of the warfare for life in the vacant lot or the possibility of overproduction by corn will lead directly to the structure and function of the various parts of the plant which enable it to carry on its life processes so successfully, namely:

The root as a holdfast and absorbing surface.

The stem as a passageway for materials and a support for the leaves.

The leaves as a means of carrying on photosynthesis and other food manufacture and respiration.

The flower followed by fruit containing seeds which provide the plant's means of reproduction. This topic should give the pupil a general understanding of the green plant as an organism capable of maintaining its own independent existence and of manufacturing the food supply not only for itself but also for the remaining life upon the earth, including the food supply of man. With this outlook it is possible to review and enlarge upon the work in hygiene and sanitation previously done. This work should show the beneficial work of bacteria, or nitrogen-fixing organisms, as well as their relation to the nitrogen cycle in general. It should show the part the bacteria play in the production of dairy products and in the ordinary processes of the kitchen. The other saprophytic and parasitic plants may well be studied here. The study should show the constructive work of green plants, coupled with the dependence of animals upon green plants for their food. The kinds and sources of food, food values, balanced rations, and food economy should be studied.

Insects as plant enemies, together with birds as the natural enemies of insects, may be studied from the point of view of the balance of life and its relation to home, farm, and industries.

Following a general view of the structure and work of plants and animals and their interrelation with each other and with man, the physiological processes may be taken up in some detail, beginning with plants and extending through the animal studies to man. These functional studies in green and nongreen plants, protozoa, insects, fish, frog, birds, and man toward the end of the course will serve as a strong unifying element to the pupil, revealing his place in the series. This series of type studies will review and organize what has been learned and give opportunity for much added interest

and knowledge. Such studies will help the pupil to recognize himself as a part of the subject of biology, constantly depending upon his environment and constantly affecting it. A much larger place than is usual should be given to the study of mammalian life.

The functional work may be vitalized by the use of skeletons of man and the frog supplemented by any other available ones, as fowls, rodents, etc. If the pupils supply these, the interest will be keener. The organs of mammals, as heart, lungs, etc., obtained from the meat market, are also valuable illustrative material. The culmination of this study should be an increased interest in personal hygiene and sanitation.

A good opportunity is open to biology teachers who have the right point of view in giving much-needed help regarding the biology of sex. An increasing number of good biology teachers are undertaking this phase of instruction, and testimony of youths and parents shows favorable results from this natural and nonsentimental approach. This important subject should not be presented to high-school pupils from its pathological aspects. So much opposition to sex education has been aroused in the past by ill-advised and wholesale teaching that, in the judgment of this committee, it is well to advance slowly, even though the need for this kind of work is urgent. The whole success of the movement depends on well-trained, sympathetic teachers well endowed with common sense. Important, however, as is the teaching of the facts and the hygiene of reproduction, a knowledge of these alone does not insure boys and girls against bad practices.

To the knowledge of what is right must be added the will to do the right. Hence, the committee believes that all physiological instruction relative to sex should be supplemented and strengthened by sane appeals to the ethical and religious nature of boys and girls.

Throughout the course an effort should be made to have pupils know the names of the common plants and animals, not for the sake of the name, but as a matter of convenience and pleasure in knowing them.

The contributions of the great biologists and the significance of these contributions should be emphasized. Darwin, Pasteur, Harvey, Mendel, and many others should stand in the pupil's mind in definite connection with real contributions to man's welfare.

Hard and fast requirements in either general science or biology ought not to be fixed by any committee or by any higher institution, because of the wide variations of physical environments, fauna, and flora. Different types or courses are often needed in urban, suburban, and rural situations. Any work of the committee, therefore, along the line of formulating content should be accepted as an

attempt to give a maximum of suggestions and a minimum of prescription.

Teachers should select material best adapted to local conditions, should plan out in advance the work that is to be done, and should improve the course with each year of their experience. In an agricultural community special study should doubtless be made of the plants and animals of local economic importance. In large towns and cities, community sanitation and civic betterment will receive major attention. Every pupil, however, whether in the country or the city, should be given such instruction in the knowledge and care of his body that there will be an improvement in the health conditions and general efficiency of the community.

F. *Methods.*—Observations, projects, experiments, excursions, individual reports upon significant topics, textbook assignments, quizzes, and conferences offer a rich and varied choice of methods of work. Each teacher should use the methods best adapted to his students and to the environment of the school in which he is teaching. Biology lends itself readily to the topic-project-problem method of teaching, since centralizing themes are abundant.

In field or museum excursions the teacher should know in advance the material available and the use to be made of it. Field trips are often merely out-of-door excursions. They should be definite and must be used in later work.

Laboratory work should be planned so carefully that time is not wasted in detailed microscopic work, in experiments which can not be understood, and in elaborate drawings to keep the children occupied until the end of the period. Information should be freely and interestingly given by the teacher to stimulate the student to seek more knowledge at first hand. Laboratory work should usually precede textbook assignments or library references, but should follow when very difficult experiments are to be undertaken. Since most high-school students do not know how to use books effectively, these assignments and references should be very definite. A rich fund of collateral reading regarding plants and animals should always be available.

Experiments, results, conclusions, observations, and drawings should be accurately recorded. Neatness in these records is desirable, but this should not be exalted above thinking and understanding. Careful labeling of drawings is important; careless spelling and ungrammatical sentences should not be tolerated.

The laboratory method in science was such an emancipation from the old-time bookish slavery of prelaboratory days that many teachers have been inclined to overdo it and to subject themselves to a new slavery. It should never be forgotten that the laboratory is

merely a means to an end. The dominant aim in all laboratory instruction should be to develop a consistent chain of significant ideas to which the laboratory may serve to give concrete experience and instruction. The primary question is not what plant or animal types may be taken up in the laboratory, but what ideas may best be developed in the laboratory.

Too often the study of plant or animal takes the easiest rather than the most illuminating path. It is easy, for instance, particularly with a large class of restless pupils who apparently need to be kept in a condition of uniform occupation, to kill a supply of plants or animals, preferably as nearly alike as possible, and set the pupils to work drawing the remains. This method is often supplemented by a series of questions designed to keep the students busy awhile longer. These methods are usually unprofitable.

The ideal laboratory is only a reasonably good substitute for out-of-doors. Any course in biology, when confined within four walls wholly, even if these walls be those of a modern, well-equipped laboratory, is in some measure a failure. Living things, to be appreciated and interpreted correctly, must be seen and studied alive, if possible in the open, where they will be encountered in life. The study of a plant or animal in the place in which it lives successfully is just as important as the study of its shape or function. Experience has shown that young students usually lose enthusiasm for biology study if they constantly work with preserved materials. In general, it is wise to study plant and animal material common in the environment. Right mental processes of observation and reasoning are best developed in connection with those real biological situations which are encountered in ordinary affairs and in ordinary needs.

G. *Content of special biological sciences.*—When separate courses in botany and zoology are taught they should seek, in the main, to attain the educational results outlined above for general biology.

With the modern point of view botany will teach the principle of soil replenishment by living organisms, large and small, soil sterilization, and soil inoculation. There will be more practical work with plants as in forestry, tree planting, tree surgery, pruning, grafting, budding, artificial pollination, and plant breeding. There should be a wider use of the indoor garden. Home gardening and work in the field should be directed by the teacher in botany, and work in garden or field should be credited in the botany course.

In zoology the study of invertebrates should not consume over one-half of the course and the study of mammals should be developed so as to become more useful in zoological study. The classes of animals to be chiefly studied should be mammals, birds, insects, and protozoa. There should be constant use of vivaria, ponds, wooded tracts, and farm lands.

III. CHEMISTRY.

A. *Why reorganization is necessary.*—In addition to the general reason calling for reorganization of science in secondary schools, which have been stated in the first section of this report, the following considerations apply particularly to chemistry:

1. The average person looks upon chemistry as a mysterious, occult science, tinged with necromancy. This almost superstitious ignorance prevents appreciation of the chemist's power to serve society. In industry it is likely to result in great economic waste through failure properly to utilize raw materials, develop by-products, and apply chemical methods of control to processes of manufacture. The high-school chemistry course in its reorganized form should attract a larger number of pupils and do much to supplant this ignorance by a measure of broad understanding.

2. In the past, chemical laws, theories, and generalizations have usually been taught as such, and their applications in industry and daily life have been presented largely as illustrative material. In the reorganized course, this order should be reversed. Laws and theories should be approached through experimental data obtained in the laboratory and through applications with which the pupil is already familiar and in which he has a real interest.

3. In the past, chemistry courses over-emphasized theories, concepts, and information of value principally to those who will pursue advanced courses. A course which emphasizes the chemistry of industry, of commerce, of the soil, and of the household furnishes a wider outlook, develops a practical appreciation of the scope of chemical service, and moreover arouses an interest which leads naturally to further study.

4. The war showed the lack of a sufficient number of chemists trained to work out such problems as arose in that national emergency. The reconstruction period and the new conditions of world competition in trade will increase the demand for specialists in the chemical problems of manufacture. High-school courses in chemistry should therefore be so reorganized as to arouse an interest in the science of chemistry, and thereby stimulate more and more pupils to specialize later in this and related fields.

B. *Principal aims.*—The principal aims in teaching chemistry in the high school should be—

1. To give an understanding of the significance and importance of chemistry in our national life. The services of chemistry to industry, to medicine, to home life, to agriculture, and to the welfare of the nation, should be understood in an elementary way.

2. To develop those specific interests, habits, and abilities to which all science study should contribute.

The powers of observation, discrimination, interpretation, and deduction are constantly called for in chemistry and are so used in this subject as to require a high type of abstract thinking. The principles and generalizations of chemistry are often difficult. For this reason chemistry should occur in the third or fourth year of the high school.

3. To build upon the earlier science courses, and knit together previous science work by supplying knowledge fundamental to all science. Coming after at least a year of general science, and usually also a year of biological science, the work in chemistry should further use these sciences. (It should furnish a new viewpoint for the organization of science materials, and develop wider and more satisfactory unifying and controlling principles.) By this means the desirable element of continuity in the science course will be secured.

4. To give information of definite service to home and daily life. This aim has been the chief influence in reorganizing high-school chemistry courses, and will undoubtedly produce further changes. The criterion of usefulness, as a basis for the selection of subject matter, should not be limited to the immediately useful or practical in a narrow sense, but should be so interpreted as to include all topics which make for a better understanding of, and a keener insight into, the conditions, institutions, and demands of modern life.

5. To help pupils to discover whether they have aptitudes for further work in pure or applied science, and to induce pupils having such aptitudes to enter the university or technical school, there to continue their science studies.

C. *General considerations concerning content and method.*—This statement is based on the assumption that chemistry will usually be given in the third or the fourth year of the four-year high school. Investigation shows that a little more than one-half of the four-year high schools present chemistry in the third year, and that pupils electing chemistry usually have had one year of general science and often a year of biological science.

(1) Difficulties.—Some difficulties in organizing courses in chemistry on the basis of individual and specific pieces of work are:

(*a*) Many of the most important principles are impossible of direct or experimental proof. They can not be demonstrated in specific, individual problems, and hence can not be grasped easily by the immature mind. These concepts must be accepted on the basis of their service to the science and the useful conclusions based upon them, for example, the assumptions of the atomic hypothesis and the rule of Avogadro.

(*b*) The number of important principles and facts is so great that organization of the information supplied by discussion, investigation, and experiment is difficult. Appreciation of the science as

such is impossible until the bases for establishing relationships and controlling facts are developed.

(c) Many problems and questions which the pupil tends to raise involve complex phases of chemistry, or ideas too advanced for his understanding.

Some motive, some compelling desire to know, must actuate the pupil in any study which is really educative. Progress in chemistry, therefore, is dependent upon a specific purpose, a conscious need to learn the facts and their underlying causes or explanation. The educational value of any problem depends upon the degree to which the pupil makes it his own and identifies himself with it, rather than upon its concreteness, or the useful applications involved, or the familiar associations connecting it with other problems, important as these considerations are. The basis for organizing a course in chemistry should lie in the changing character of the pupil's interest and the increased intensity of his needs as a result of his growing abilities and of his increased power to direct and use them. A topic in chemistry which would have seemed abstruse and uninteresting a year or even a few months earlier may suddenly become a real problem to the pupil. Such questions as what the constitution of things really is, what properties the atoms possess, or why the volumes of gases have such simple relations to one another, may become problems of real significance to the pupil. Ultimate causes and reasons appeal to the adolescent pupil. Problems having to do with home, farm, local industries, the civic and the national welfare, are limited only by the time and energy available for their pursuit.

(2) Laboratory work.—The relation between class and laboratory work is a most important problem for the chemistry teacher. Unfortunately, theory and practice have not been properly related. Some of the reasons for this situation are:

(a) It is difficult to correlate recitation and experiment. One lags behind the other. The remedy is a greater flexibility in the program, so that the time may be used for either purpose as needed. There is a growing tendency to make all periods of a uniform, 60-minute length instead of 40 or 45 minutes on some days and 80 and 90 minutes on other days. This change helps to make possible a closer correlation between experiments and the discussion of them.

(b) Experiments often fail of their object because of insufficient directions, failure to provide needful data, or lack of a definite and clear purpose. This needful information must be supplied, but in such a way as to stimulate interest and raise questions to be answered by the experiment itself. Some teachers prefer to take the first few minutes of each laboratory exercise in talking over the work, suggesting important questions, pointing out difficulties, and giving necessary cautions. It might be well to embody more of the infor-

mation usually supplied by the text in the laboratory directions themselves, so that they would be thought-producing and stimulating rather than simply directions for manipulation and observation.

(c) Too many experiments involve repetition of work described in the text or have no outcome beyond the mere doing and writing in the note book. Unless the experiments contribute to the recitations and provide data or information which is used, they are largely a waste of time.

Laboratory experiments, to accomplish their purpose, must concern a problem or a question which the pupil seeks to answer because he is interested in doing so. The titles of experiments can often be worded so that they become suggestive by stating them in problem or question form. For example, instead of the title "Mordant dyeing," a better one would be, "Why are mordants used in dyeing?" Or, in place of "Equivalent weight of magnesium," substitute "How much magnesium is needed to produce a gram of hydrogen?" Or, for "Analysis of ammonia" substitute, "What is the most economical brand of household ammonia to purchase?" The mere rewording of a title itself is not enough. The question itself must be a vital one to the pupil either through his own independent thought or as a result of the stimulating influence of the class discussion.

Flexibility in the keeping of notebooks is desirable, provided that the essential facts and conclusions are always included. The notes should usually include a clear statement of the problem in hand; a description of the method of procedure, making use of a diagram of such apparatus as may have been used; and a statement of results and conclusions, with answers to any specific questions which have arisen. If the pupil's notes cover this ground, they should be accepted, and he should be encouraged to work out any plan of his own for the improvement of his notebook. To require all to use exactly the same plan may make the checking of notebooks more easy and their appearance more satisfactory, but it stifles the pupil's originality and prevents him from discovering and correcting his own faults in this direction.

The notebook has often been a fetish with chemistry teachers, and time has been demanded for making a record which, while beautiful in appearance and completeness, is yet full of needless repetition and useless detail. The notebook should not destroy the interest attached to an experiment, for the experiment is not for the notebook but for the pupils' clearer understanding of important chemical facts. Only when properly used will the notebook enhance the value of laboratory work.

The teacher in the laboratory should not set up apparatus, weigh out materials, or attend to other purely manual matters, which in most cases should be done by the pupils. The teacher should see

that pupils are trained to observe accurately, to draw correct inferences, to relate their conclusions to the facts of previous experience in and out of school, and to find the answers to questions and problems brought out.

It is proper that the teacher should perform laboratory demonstrations that are too difficult, too costly in materials, or too long for student assignment. These should be done with model technique, for the pupils will imitate the teacher's methods. They should be recorded in the student's laboratory notebook just as any other experiment, but with the notation "performed by instructor."

(3) Aids to the chemistry teachers.—(*a*) Reference books and magazines. A part of the requisite equipment of every chemistry department is a well chosen set o reference books, available and in constant use. Each pupil will need a textbook as chief reference book, but he should find it necessary to use additional books. There should be provided duplicate copies of the better textbooks, other books on special subjects, articles, newspaper clippings, etc. These books are necessary in order that the pupil may investigate all the questions that arise. He will profit by the training which comes from learning how to find the answers to his questions from many sources of information. These books should provide entertaining reading by which the pupil's interest in things chemical may be stimulated and developed.

(*b*) Individual topics and reports. The study of special topics and reports upon them by individual members should be a regular feature of the class work. Pupils should be encouraged along the line of their special interests, and lists of topics should be suggested by the teacher from time to time. By this plan individual initiative and ability may be given encouragement and the whole class stimulated.

(*c*) Optional experiments. The pupils should be given encouragement to bring in materials to test in various ways and, whenever time permits, to perform additional experiments, the results of which may be reported to the class. In the chemistry laboratory it is not necessary or desirable that all pupils be always at work on the same experiment. Even if the experiment is essentially the same, a variety of materials may often be used, and each pupil may contribute to the general result. For example, if colored cotton cloth is to be bleached by chloride of lime, let the pupils bring in samples from home so that a variety of colors may be tried out; or, if the presence of coal-tar dyes is to be tested in candy or food products, each pupil should be responsible for his own materials. In this way the work of the class will have a breadth and scope which will make the results more significant.

(*d*) The review. In chemistry the number of detailed facts is so great, and the application of its principles so wide, that from time to time a definite plan for insuring proper organization of ideas is needed. These need not be formal reviews and tests, though such have their place, but they should always be exact and comprehensive. Quizzes should frequently follow excursions or a series of laboratory experiments upon some central topic of study. These should be conducted in such a way as to lead pupils to organize knowledge for themselves rather than to force upon them a classification of the material that does not develop from their own work.

(*e*) Excursions. Many topics in chemistry should be initiated or supplemented by an excursion to a factory or industrial plant where the operations may be viewed at first hand. If such excursions are to be really profitable, there must be a very definite plan covering the things to be seen. The first recitation after such an excursion should be devoted to answering questions suggested by what has been seen and to defining further studies based upon these observations. The great value of the excursion lies in the opportunity to give the pupil a vivid conception of the practicability of chemical knowledge and to make him see that there is a definite relation between the test tubes and beakers of the laboratory and the vats, concentrators, and furnaces of the factory.

(*f*) Science clubs. Whenever the number of students taking chemistry is sufficient to warrant the formation of a chemical club, this is desirable. The members of the chemistry class should be encouraged to join or organize a science club and to make it an attractive feature of the school life. In small schools a science section may be a part of a literary or debating society, thus widening the interests served by such an organization. Such a club provides motive and opportunity for the exercise of individual interest and effort, and the interest of the whole school may be extended through it.

D. *Specific principles controlling reorganization.*—1. Larger units of study.—The number of important principles and facts in chemistry is so great that there is grave danger that many topics will remain isolated and unorganized in the mind of the student. Reorganization should develop larger units of study connected by and emphasizing natural relationships.

(*a*) These larger units of study should be presented in such a manner as to appeal to the pupil personally.

Interest is not likely to be aroused if the more important elements are taken up in the order suggested by the periodic system. It is equally destructive of enthusiasm to use one unvarying plan of study with every element, as occurrence, physical and chemical properties, methods of obtaining, uses, important compounds, etc.

(b) The selection of these large topics should not be handicapped by the traditional content of the course. Traditional divisions should be retained only when they are found to aid the pupil in making his own organization of the facts and principles involved.

Such topics should show many cross relationships, necessitating the use of information previously gained in new situations and serving to fuse all into an organic whole. Thus, sudden leaps into absolutely new material would be avoided or at least greatly reduced.

As an illustration, the interesting, unified, and vitally significant topic of fertilizers can be developed out of information usually supplied under such isolated headings as nitrogen, phosphorus, potassium, sodium, calcium, sulphur, carbon, etc.

(c) Certain topics of chemistry cover wide fields. The large topic is valuable because it shows broad relations and secures the right sort of organization in the mind of the pupil. Neutralization, hydrolysis, oxidation, etc., are examples of such topics, which are constantly recurring in new phases and which should be brought out not once but many times.

2. Laws and theories.—A chemical law or theory should be taught as a generalization, justified by experimental data, or as a device to explain things that the pupil is eager to understand. Likewise, chemical mathematics should be developed through problems arising from the laboratory work or through practical problems that the chemist is called upon to solve in everyday situations.

E. *Content.*—Different introductory courses in chemistry contain much in common in that they deal with fundamental facts, concepts, laws, and theories, but the teaching of these fundamentals must be influenced by the particular conditions and purposes which control in the individual school. It is not the purpose of the committee to lay out the work in detail or to offer a syllabus, but to suggest by a few type topics the character of the organization recommended. These have been selected solely as illustrations, and no sequence is implied by the order in which they appear here.

1. The atmosphere. (A sample introductory topic.)—(a) Physical properties. Recall, or perform demonstration experiments to show, that air possesses weight, exerts pressure, expands when heated, and is compressible. Demonstrate diffusion of gases by spilling ammonia. Development in simple way of kinetic molecular hypothesis as basis for explanation. Demonstration experiments to illustrate Boyle's and Charles's laws, if needed.

(b) Air and burning. How does a candle burn? Structure of flame: Products of combustion, identification of water by condensation, soot by deposit on cold objects, and carbon dioxide by reaction with lime water. (Water may be electrolyzed to show its composition.) Definitions of element, compound, mixture, and chemical changes.

Fuels: Composed chiefly of carbon and hydrogen. Prove by burning coal, gasoline, kerosene, gas, wood, etc. Luminosity of flame due to carbon. Kindling temperature.

(*c*) Oxygen. Laboratory study of oxygen and burning in oxygen contrasted with that in air. Action on metals.

(*d*) Composition of air. Analysis, using phosphorus and iron filings. Residual nitrogen tested for effect on combustion. Nitrogen as diluting material in air. Is it fortunate air is not all oxygen?

(*e*) Other questions to be considered or used for assignment purposes: How was oxygen discovered? How abundant is it? How are rusting and decay different from burning? How is spontaneous combustion caused? What precautions should be used to avoid it? Why is perfect combustion desirable in furnaces and steam-power plants? Why is imperfect combustion dangerous in stoves or grates? Oxyacetylene process for welding and cutting. How is oxygen prepared for commercial purposes? Oxygen as necessary to life. Ventilation for health and comfort. Corrosion of metals, causes and prevention.

2. Purification of water.—(*a*) Importance of the question from standpoint of health and industry.

(*b*) Common impurities and their removal: Sedimentation and filtration for suspended matter; boiling to destroy bacteria; coagulation to remove sediment and bacteria (use alum and lime water); distillation to remove dissolved minerals; chlorination with bleaching powder (chloride of lime; add solution of bleaching powder to water and taste); tests for sulphates, chlorides, calcium compounds, and organic matters; laboratory testing of spring and mineral waters collected by pupils.

(*c*) How cities get pure water: Protecting the catch basin (New York); sedimentation and filtration methods (St. Louis); coagulation and precipitation method (Columbus); demonstration experiments to illustrate; excursion to local pumping station and study of system of purification employed.

(*d*) Soft and hard water, temporary and permanent varieties; effect of hard water in tubes of steam boilers (specimens of boiler scales); why a laundry needs soft water; action of hard water on soap; softening power of borax, ammonia, soda, soap, and washing powder of various brands.

(*e*) Sewage disposal: Relation to pure water supply of other cities or communities; dilution method (Chicago drainage canal); oxidation methods (spraying, activated sludge); methods for small towns and rural homes; the septic tank.

3. Limestone, lime, and allied products.—(This topic is developed in considerable detail, suggesting a possible plan for correlating

laboratory and classroom work, excursions, and individual reports, and showing how drill in equation writing and problem solving may naturally arise.)

IN THE LABORATORY.

1. Excursion to limestone bluff or quarry. Collection and display of limestone fossils. Observe, on the way, any limestone or marble used in buildings. Visit limekiln and hydrating plant if possible.

2. Note texture, solubility, reaction to moist litmus, and effect of acid on a limestone lump. Heat the lump, note changes in the above properties.

3. Using quicklime, note heat on solution, reaction to litmus, etc. Pour the following mixtures in the form of thick pastes, into match-box molds: (1) Lime and water; (2) lime and sand and water; (3) lime, sand, cement, and water. Allow to stand until hardened. Examine these specimens for suitability as mortar. Test these specimens, also old mortar, with acid. Test evolved gas. Examine both in place and as laboratory specimens, samples of mortar, plaster, concrete, reinforced concrete.

4. Note properties of a piece of native gypsum. Heat a crystal, note water driven off and change in form. Pour thick paste of plaster of Paris into a match box, and press into it some object such as a nut, small brass ornament, or small clay model, previously greased with vaseline. Let paste harden thoroughly.

5. Test the solubility of a limestone lump in (a) distilled water; (b) rain water; (c) distilled water into which carbon dioxide has been passed to acid-

IN THE CLASSROOM.

1. Discussion and explanation of the mode of limestone deposit. Observation of fossil shells, corals, skeletons. Reference to geology text. Study of metamorphic limestone (marble) and uses of marble and limestone in buildings.

2. Discuss visit to limekiln, or use diagrams. Describe use of "limelight" in stereopticons, etc. Derivation of the phrase "to seek the limelight."

3. Make sure that the students can write equations, and fully understand the chemical reactions from limestone, calcium carbonate as quarried, to calcium carbonate as the final product in mortar or concrete. Prepare and discuss the following special reports: "Manufacture of lime in large quantities;" "Manufacture of hydrated lime;" "The use of lime as a disinfectant;" "The use of lime (limewater) in medicine;" "Use of lime in whitewash;" "Source and manufacture of cement;" "The use of mortar and concrete in the construction of walks, buildings, bridges, posts, pipes, tile, furniture;" "The proportions of different ingredients, the erection and filling of forms, mixing machines, etc.—the reports of an interview with a practical plasterer, and concrete foreman;" "Artificial building stone."

4. Discuss occurrence of gypsum. Equations for heating gypsum and for setting of plaster of Paris. Prepare and discuss special reports: "Manufacture of plaster of Paris" on a large scale; "Uses of plaster of Paris in molds, statuary, for broken bones, white coat for plaster, etc.;" "Manufacture and uses of calcimine."

5. Discuss solubility of limestone in carbonated rain water. Special report: "The formation of caves and sink holes"; "The formation of stalac-

ity. Filter and test for calcium with ammonium oxalate. Pass breath through limewater. Burn a splint in a bottle, add limewater, and shake. Pass carbon dioxide through limewater until the precipitate is redissolved.

tites and stalagmites." The limewater test for carbon dioxide. Equations for these processes.

6. Shake any of above solutions in which some limestone has dissolved with soap solution, adding drop by drop. Prepare the following samples: (a) Distilled water; (b) bubble carbon dioxide through water, and shake with ground limestone, filter; (c) add several drops of saturated calcium sulphate solution to water; (d) hydrant water. To one-third of each add soap solution (approximately Clarke's standard) from burette and record amount needed to form suds. Boil one-third of each vigorously. Observe any precipitate. Filter and add soap solution as before. To one-third of each add a few cc. of washing soda solution, then soap solution as before.

Test the effect of other softening agents—ammonia, borax, lime, commercial softening agents, and boiler preparations.

6. Discussion of temporary and permanent hardness. Methods of softening each. Complete set of equations. (This is an excellent exercise on interpretation of results.) Require special reports: "Household experience in the use of river and spring water in washing and cooking"; "The use of hard water in boilers" (illustrated with specimens of boiler scale); "Comparative cost of softening water with different agents, including soap"; "What are commercial softening agents composed of?"

It is believed that the softening power of washing soda is more logically discussed under this heading than in the chapter on "Sodium," and that "Hardness of water" should be treated in detail here unless included in such a topic as the "Purification of water," previously outlined. At any rate, the cross reference should be made, the facts reviewed, and the principles extended to the new topic.

7. Test solubility of powdered limestone in weak acids—dilute hydrochloric, carbonic, citric.

Test soil in a swampy place for acidity, sprinkle with powdered limestone and test several days later.

Extract soil with HCl—burn bones and extract ash with HCl—coagulate milk, filter—and test all filtrates for calcium with ammonium oxalate.

Examine face powder, testing for chalk or gypsum.

Examine blackboard crayon.

7. Special reports and discussions: "What causes acid soils?" "What crops will not grow in acid soils?" "The use of ground limestone (and plaster) on acid soil"; "An interview with a progressive farmer or fertilizer salesman on method of calculating the amount of limestone needed per acre of soil"; "The presence of calcium compounds in plant and animal tissues"; "Use of powdered limestone for miscellaneous purposes."

4. Simple inorganic preparations.—The introduction of simple, inorganic preparations to the laboratory work of the second half of the year furnishes every desirable opportunity for the bright pupil to test his ability. It gives him a chance to do extra work, learn additional chemistry, and gain considerable skill in manipulation. The materials for this work include: Copper sulphate from copper scraps; copper nitrate as by-product from preparation of nitric oxide; ammonium-copper sulphate from copper sulphate; mercu-

rous nitrate and mercuric nitrate from mercury; boric acid from borax; zinc sulphate as a by-product of the preparation of hydrogen; sodium thiosulphate from sodium sulphate; mercuric sulphocyanide from mercuric nitrate; zinc oxide from zinc sulphate; and potassium nitrate from wood ashes.

It has been demonstrated that the pupils are greatly interested in such experiments and spend many hours willingly in completing these preparations.

The committee does not desire to outline other topics in detail, since too much elaboration might tend to retard rather than stimulate the proper reorganization of the chemistry course. The following list is added to show a great variety of interesting topics which may be drawn upon for illustrative and informational purposes and for developing the fundamental generalizations of chemistry. Local conditions, the interest and needs of the particular class, and the time available should determine the choice of such topics and their proper organization into the larger units of study. The following list could be greatly extended:

Glass.—Crown, flint, lead, special glasses, coloring of glass.

Clay products.—Brick, pottery, chinaware, porcelain.

Artificial stone.—Lime, plaster, mortar, hydraulic cement, concrete stucco, plaster of paris.

Fertilizers.—Problems of soil fertility, elements needed by growing plant and function of each. Photosynthesis and carbon dioxide cycle. Nitrogen cycle and function of nitrogen fertilizers. Use of limestone and phosphate rock.

Coal.—Composition and fuel values of different varieties. Distillation of coal tar, light oil, middle oil, heavy oil, tar, pitch. Relation to dyes and explosives.

Petroleum.—Fractional distillation into burning oils, solvent oils, lubricants, paraffins. Problem of gasoline supply and possible exhaustion of petroleum.

Wood.—Distillation of wood to produce methyl alcohol, acetone, acetic acid, charcoal.

Explosives.—Black powder, nitroglycerine, dynamite, guncotton, trinitrotoluene. Relation to nitrogen fixation by arc, Haber, and cyanide processes.

Paint, varnish, etc.—Oil paints and driers, varnish, shellac, copal. Linseed oil, oilcloth, linoleum.

Pigments.—White lead, red lead, iron oxide, lead chromate, etc.

Textile fibers.—Natural and artificial silk. Wool: Scouring, bleaching, felting, etc. Cotton: Bleaching, mercerizing, etc.

Dyeing.—Direct and mordant dyes.

Cleansing agents.—By acid: Oxalic, hydrochloric. By alkalies: Caustic soda, soap emulsification. By special solvents: Carbon tetrachlorid, benzene. Composition of trade-marked cleaning fluids.

Photography.—Blue prints, plates; films, prints, toning, etc.

Food constituents.—Starch preparations from corn; cooking to dextrin and to paste, hydrolysis to glucose.

Sugars.—Preparation and refining of beet and cane varieties; conversion to caramel; inversion.

Fats.—Olive oil, cottonseed oil, butter, oleomargarine, hardening oils by hydrogenation.

Proteins.—Albumins, casein, gluten, peptones, gelatine, vitamines.

Beverages.—Charged waters, soda, mineral, infusions, tea, coffee, chocolate. Fruit juices (artificial flavors), fermentation.

Poisons and common antidotes.—Common inorganic drugs.

Leavening agents.—Yeast, soda, baking powders.

Matches.—Ordinary and safety types.

Adhesives.—Gums, paste, dextrin, glue, casein, water glass (sodium silicate).

Inks.—Various types.

Refuse disposal.—Sewerage, garbage; fermentation and putrefaction; civic problems; disinfectants and deodorizing agents.

Preserving.—Sterilizing, pasteurizing, dessicating, pickling by salt and sugar; chemical preservatives and tests for them.

Metals.—Extraction processes; oxide ore, iron, sulfid ore, lead; electrolysis, sodium and aluminum; extraction of other metals may be studied by comparison with these.

Metals used for basic purposes, iron, copper, aluminum, lead; for ornament, gold, silver, nickel; for alloys, bronze, brass, solder, type metal, antifriction or bearing metals, fusible metal.

F. *Differentiated chemistry courses for certain curriculums.*—The content of the regular course in chemistry has been indicated in the two sections just preceding. It is designed to meet the needs of young people and to enable such as need it to count the work done for college entrance. It remains to show how modified chemistry courses may be offered to meet the requirements of special groups of pupils by including topics and problems bearing more directly on the work these pupils will enter or in which they are already engaged. These differentiated courses are chiefly of two types, those which aim to better prepare girls for home making and home management and those offered in technical curriculums to suit the needs of students primarily interested in industry. These two types are briefly considered.

1. Courses in household or domestic chemistry.—There are two methods which are followed in teaching household or domestic chemistry. Girls may be taught the regular chemistry the first half of the year and the second half they may be given instruction in topics relating directly to the home, or a year's course in household chemistry may be given. Each school should choose the method best adapted to its organization. If a year's course of household chemistry is given, the first half should emphasize the study of chemical change, combustion, water, air, acids, bases, salts, and chemical formulas. In the second half the following topics should be emphasized: Carbon compounds in their relation to fuels, cooking, and foods; metals used in the home, as iron, copper, aluminum, and silver; textiles and cleaning agents; dyeing and removal of stains; fertilizers and insecticides; disinfectants and antiseptics; poisons and their antidotes; paints and varnishes.

2. Courses in technical curriculum.—In many technical curriculums there is a demand for a two or three years' course in chemistry. In such cases the elementary course is given in the tenth or eleventh year, followed by qualitative analysis and organic chemistry. Some teachers may prefer to give in the second year a half year of advanced general chemistry and a half year of qualitative analysis. In addition to these, special courses for certain types of students should be offered if there are facilities and if there is sufficient demand for the work. To illustrate, a few courses which have been successfully tried in the continuation and evening classes of a large technical high school are described:

(*a*) Chemistry for nurses: Girls who study nursing find it of great advantage to know something of the fundamental principles of chemistry. Many of the girls have not completed a high school course and have not studied chemistry. For such girls a special course consisting of laboratory work and discussion two afternoons a week for 13 weeks is given. This course covers elementary chemistry through carbon compounds, and emphasis is placed on the study of substances used as drugs and in the home.

(*b*) Chemistry for electroplaters: A large percentage of men actually engaged in the electroplating of metals have only a common school education, and their work is done mechanically. Without a knowledge of the fundamental principles of chemistry and electricity the men find much difficulty in solving their problems. To remedy this condition the National Society of Electroplaters has been organized. At least one technical high school has been cooperating with this organization the past two years. A special class for electroplaters has been conducted in the evening school. The men study elementary chemistry, electricity, and volumetric analysis and discuss their problems with the instructor. The students are very enthusiastic over the course and they have become more intelligent and skilled workers.

(*c*) Chemistry for pharmacy: Some high schools offer a course in pharmacy. For this purpose a three-year course in chemistry is desirable. The first year the pupils study elementary chemistry, which differs from the regular course by emphasis on technique, preparation of tinctures and ointments, the study of drug manufacturing, and chemical arithmetic. Qualitative analysis is studied the second year, quantitative analysis and organic chemistry the third year.

(*d*) Special courses for workmen and foremen in chemical industries: Some manufacturers permit their employees to study in technical high schools for one afternoon a week in order to make them more intelligent workers. The chemistry course in these cases is

adapted to the needs of the individuals. Where facilities permit there is opportunity for great service to the men and the community. A course in simple, inorganic preparations, such as ammonium, sodium, and potassium compounds, is valuable to teach in connection with or following the elementary course.

IV. PHYSICS.

A. *Why reorganization is necessary.*—The need for a thorough reorganization of physics is evidenced by the following considerations:

(1) The content and methods of presentation in vogue for the past 20 years have failed to make a vital appeal to most pupils. With the large majority the subject has aroused little enthusiasm.

(2) The content has been too largely that handed down by tradition through the textbooks, which were largely based on the logical organization of subject matter, neglecting the interests of pupils and the laws of learning. Some of the material is obsolescent or wholly obsolete, because it treats of applications of physical theory to problems now of little or no value, and much of it has no connection with the present-day activities in the industries, in municipal enterprises, on the farms, and in the homes.

(3) The teaching of the past has too frequently assumed that a principle may be readily grasped if only it be once stated in clear language and illustrated by a few examples, and that it may then be generally applied with comprehension and completeness. It is now recognized that principles may be best arrived at and comprehended through solving problems. From such experiences the teacher should guide and stimulate the pupils to recognize that they must arrive at the generalizations by their own mental processes. In order to have the power to apply these principles, pupils must have practice in applying them. Such applications not only make the principles usable, but also clarify the understanding of the principles themselves and stimulate the interests of the pupils.

(4) With a few exceptions the class work and the laboratory work have not been intimately connected. A formal list of laboratory experiments has been made the main feature of the course, and formal textbook recitations not closely related to the laboratory experiments have completed the program. This failure to coordinate laboratory work with recitations and class discussions is pedagogically unsound and is wasteful of effort.

(5) The traditional courses do not contribute as physics can and should to help pupils to understand the higher type of vocations in which physics is fundamental, such as mechanical and electrical professions and trades. This failure prevents physics from making the

contribution which it should render in vocational and educational guidance, and also in giving a liberal understanding of the world's work.

(6) Many schools have already made changes which have resulted in marked improvements in interest and in outcome.

B. *Local surveys needed.*—In order that the teaching of physics may be adapted to actual needs, the teachers in each school should make a careful survey to determine what physical facts and phenomena are especially significant in local occupations and contacts, since pupils of high-school age naturally look forward to taking active part in adult vocational, social, and civic life. These facts and phenomena, collected in the survey of the whole subject, should be analyzed and classified with reference to the principles of physics that underlie them, with reference to the wideness and frequency of their uses, and with reference to the interest and teaching utility of the projects arising therefrom.

C. *Aims.*—Physics, in common with the other science courses in secondary education, should be directed so far as possible to the realization of the seven main objectives of education defined by the Commission on the Reorganization of Secondary Education to be: Health, command of fundamental processes, worthy home membership, vocation, citizenship, worthy use of leisure, and ethical character. To realize these objectives, education must develop certain specific interests, ideals, habits, and powers, as well as an essential body of knowledge.

Among the habits and abilities which should be developed in all science teaching and which should be emphasized in physics instruction, the following may be enumerated:

(1) Observing accurately significant facts and phenomena, and at the same time neglecting distractions and details that have no direct relation to the problem in hand.

(2) Developing a methodical plan of attack before beginning an experiment or set of observations.

(3) Using eyes, ears, and hands before consulting books, when knowledge of phenomena is sought.

(4) Maintaining system, order, and neatness in the arrangement of apparatus and appliances for the observational and experimental work.

(5) Using care and intelligence in the manipulation of tools and apparatus, endeavoring to acquire a good technique.

(6) Making measurements where quantitative knowledge is required, always carefully, intelligently, and as accurately as is demanded by the nature of the knowledge sought, but not more so.

(7) Making and recording calculations accurately and rapidly, using practical aids in computation such as logarithms, multiplication tables, and the slide rule.

(8) Maintaining accuracy and methodical procedure in arranging and tabulating the data obtained from experiments and observations.

Physics must teach its pupils to consider common physical phenomena carefully and to interpret and classify observations, to the end that the knowledge gained may become orderly in arrangement. For example, if a flamelike luminosity is observed, is it due to combustion of gases, or to incandescence caused by the passage of an electric current, or to electrostatic discharge, or to phosporescence? When we seek to explain it we are really referring it to its proper class and attributing to it the properties that we know belong to others of the same class. We are trying to record, predict, or indicate its properties by placing it first in a large class, then in a smaller class within the larger, and so on, until we get it into the smallest class we know. We then know something about its causes and effects because we know it to be like others in that class whose properties are already familiar. By practice in making such interpretations, certain habits, methods, and ideals as to interpretation may be developed.

It is not the purpose of this report to present a syllabus in physics. Teachers should make their own, because the subject matter must be adapted to the needs of the pupils, and these needs vary widely throughout the country. The subject matter should be made simple enough to be clearly comprehended by the pupils. It should be of fairly obvious utility, from the pupil's standpoint, in the accomplishment of some worthy purpose. It must have the greatest number of elements in common with everyday situations, within the experience, interest, and knowledge of the pupils, or in common with the situations in which they may reasonably be expected to take part when they have become adults. Information that does not square with these criteria is not likely to afford real training in the habits and abilities outlined above.

Considerations to be kept in mind in teaching physics are summarized as follows:

(1) Adapt the organization of physics to the nature and needs of the pupils, bearing in mind especially adolescent characteristics and individual differences.

(2) Select subject matter thoughtfully, choosing that amount and kind which, in view of the nature and needs of pupils, is likely to be individually and socially useful. So present it that it will be actually usable when needed.

(3) Use constantly those types of procedure that are of the highest value and widest application both for the individual and through

him to society. The methods of teaching and control should be such as to cause these modes of procedure to be formed into habits.

(4) Develop as far as possible those scientific ideals that served to motivate the great discoveries and achievements of physics.

(5) Develop as far as possible scientific insight and powers of interpretation.

(6) Secure the cultural values of physics by developing tastes and appreciation for scientific pursuits, either as vocations or avocations.

(7) Acquaint pupils with the lives of some of the great leaders in science, especially those who were obliged to make great effort or undergo great sacrifice in their efforts to establish truth.

D. *Methods.*—(1) Projects.—To accomplish the aims stated above the teacher should use both individual student projects and class projects. But the project method should not be employed to such an extent as to sacrifice unity, coherence, and adequate scope.

The worthwhileness of the project must be recognized by the individual in individual project work and by the class in class project work.

When a project is adopted by an individual student, he should be encouraged to use his own initiative in devising methods for carrying it out, but should have the teacher's guidance whenever needed.

When a project is adopted by the class, initiative on the part of the class should be encouraged in the choice of methods, under the guidance of the teacher. The socialized recitation is of special importance in connection with the class project.

(2) Correlation.—The three principal methods in use during the past 10 or 15 years are the recitation method, the class-demonstration method, and the laboratory method. Theoretically, these methods were to have been closely connected in the treatment of a given portion of the subject matter; but this desirable intimate connection or correlation has not been generally maintained. The laboratory lessons often bear very little direct relation to the recitations and class demonstrations. There has been too little experimenting by the teacher or by pupils before the class.

(3) Unit of instruction.—The unit of instruction, instead of consisting of certain sections or pages from the textbook, or of a formal laboratory exercise, should consist of a definite question, proposition, problem, or project, set up by the class or by the teacher. Such a problem demands for its solution recalling facts already known, acquiring new information, formulating and testing hypotheses, and reasoning, both inductive and deductive, in order to arrive at correct generalizations and conclusions.

This method calls for an organization in which information, experimental work, and methods of attack, all are organized with reference to their bearings on the solution of the problem. The recitation,

the laboratory lesson, and the class demonstration should not be discrete and unrelated units. Each should have its part in the activities, the gathering of information, and the reasoning essential to the conclusion reached.

(4) Class conference.—The usual formal recitation should be replaced by a well-balanced combination of group and individual work. In group work the class conference fosters cooperation, investigation, reciprocal interrogation, open or free for all discussion, and the scientific method of study and problem solving, as opposed to memoriter repetition. In the class conference the teacher selects a topic suggested by one or more of the preceding exercises or assignments. By questions and smaller topic assignments the teacher leads the class to summarize the knowledge previously acquired. Additional knowledge and experiment are necessary for the intelligent understanding of the facts or principle involved in the main topic. The pupils are stimulated to set up hypotheses, to experiment, and to propose methods for testing out the different suggestions. The experiments and tests are made by teacher and pupils at the demonstration table or in the laboratory. At later conferences the final conclusions are reached. They are then applied either in securing other knowledge or in verifying and explaining practical applications as observed in the industries or elsewhere. Initiative should be given full scope in the class conference, but the discussion should be conducted in an orderly and effective manner. It may even be well to train the pupils in parliamentary rules and to insist on observance of those rules in the classroom. The teacher should endeavor to avoid dominating the discussion on the one hand, or letting it become aimless and desultory on the other hand.

(5) Laboratory work.—The high-school physics laboratory is too often thought of as a place in which to "verify laws," to "fix principles in mind," to "acquire skill in making measurements," or to "learn to be accurate observers." With a project or a problem as the unit of instruction and its solution as the motive for work, the pupil should go to the laboratory to find out by experiment some facts that are essential to the solution of his problem, and that can not be obtained at first hand by other means. With such a motive he is more nearly in the situation of the real scientist who is working on a problem of original investigation. He is getting real practice in the use of the scientific method. The problem or project should underlie the "laboratory exercise." For example, instead of aiming "to determine the specific gravity of a liquid," the pupil may be incited to find out whether the milk delivered at his door has probably been watered. This is a project of vital interest to the pupil himself and to his family at home, and it involves finding the specific gravity of the

milk. Laboratory problems in physics should provide direct and obvious connections between what immediately precedes and follows.

The following principles with reference to the conduct of the physics laboratory work have become fairly well standardized, and are recommended as important:

(*a*) The number of laboratory problems per year should lie somewhere between 30 and 50, according to the nature of the problems chosen and the circumstances controlling the work. The preference should in general lie with the smaller number, thoroughly and intelligently worked out and reinforced by frequent, subsequent applications so as to insure permanent retention.

(*b*) The schedule for work in physics should provide for laboratory periods of from 60 to 90 minutes in length.

(*c*) The maximum number of pupils that can be efficiently directed in a physics laboratory division by one teacher is 25; better work can be accomplished when the maximum is 18 to 20. If more than 25 are working in the laboratory, there should be a competent assistant in addition to the teacher.

(*d*) Each pupil should be required to keep a notebook record of all his experiments. The notes should be clear, concise, and systematically arranged, and should be repeatedly utilized in subsequent work.

(6) Notebooks.—The notebook should contain a statement of the problem; a brief description of the apparatus, materials, and procedure; tabulations of numerical data, with original calculations, when calculations are involved; the conclusions reached; and a brief statement of such precautions and sources of error as it is necessary or profitable to consider. Graphs and drawings should be used as means of expression or interpretation, not as ends in themselves. The use of printed forms, where the pupil only fills in the blanks with figures and words, should be discouraged as tending to inhibit thinking rather than to stimulate it. All notes belonging directly to the laboratory work should be recorded in the laboratory at the time of making observations or of doing the work. Original notes should be made with such method and care that copying of notes will be unnecessary.

(7) Demonstrations.—In the classroom the demonstration experiment with informal comment and running conference should be frequent, and formal lecturing the exception. The lecture demonstration, however, has its undoubted uses in high-school physics. Accounts of new discoveries in physics, demonstrated by experiments and lantern slides, will present a fascinating and effective appeal and furnish strong incentives for study. Accounts of the lives and labors of great physicists, and especially of the formative influences and character development that contributed to their great-

ness, serve to arouse human interest, crystallize ideals, and motivate effort. The help of volunteer pupils should be enlisted in the preparation of the demonstration experiments. The demonstration, when given, should be a model of clear exposition and experimental technic that will challenge admiration, arouse enthusiasm, and stimulate imitation.

(8) Excursions.—In nearly every community there are opportunities for making profitable excursions to places in which the principles of physics taught in the schoolroom are applied. The teacher should arrange for excursions at such times as best fit in with the school instruction. Every available physical device in the homes, local stores, shops, factories, waterworks, street railway or electric-lighting power plants, school heating and ventilating plant, newspaper-printing plant, telephone exchange, ice-manufacturing and cold-storage plant should be used for instruction. Mimeographed instructions prepared before an excursion will be of great service. After the excursion the things seen and their bearings on other work should be thoroughly discussed. In a few cases written reports of the excursion should be required, and the best of these should be credited as oral or written compositions in English classes.

(9) Reports.—During the year each pupil should be assigned one or more definite pieces of study to be made from books or papers, the study to be organized for presentation before the class. Assignments should be specific, giving subject, properly delimited, and usually the books or papers to be consulted, with specific citations. There should always be a report in good form made to the teacher, if not to the class.

(10) Clubs.—The science club, or society, officered and managed by pupils under teacher guidance, may prove a stimulus to science throughout the school and may become an important factor in community life. Physics should join with other sciences in the science clubs of small high schools, but in some large schools a separate physics club may be desirable. Experiments, objects from amateur natural-history collections, reports on scientific books, and articles from magazines, biographical sketches, and also occasional lectures by teachers should compose the programs.

E. *Organization.*—It is assumed that physics will be given in either the third or fourth year of the high school. Pupils will ordinarily have had one year of general science and should have had one year of biological science, and these science courses should constitute a good basis for the physics work. For example, the pupil ought to know something about matter and its states, energy, work, simple machines, and should have an elementary idea of electrical apparatus and its control; he should know how plants and animals live, their processes of food manufacture and use, and the principles and

practices of good health. In beginning a topic in physics a brief review of any related facts learned from general science and biology or from the pupil's everyday experiences should be made. The method which was begun in the first year and carried on in the second should make it possible for the pupil to advance more rapidly than otherwise in his study of physics.

(1) Problems as the basis of organization.—Whenever possible the problem should furnish the basis of organization. Subject matter should be arranged with reference to its solution. Related problems organize themselves naturally into topics. Suppose the topic is electric lighting and the problem is to find out whether a mazda lamp is more economical than a carbon lamp of the same candlepower. The laws of electrical resistance, the specific resistance of different materials, the heating power of the current, and the definitions and units in which the facts are expressed or the quantities measured should be aids in solving the problem. The skillful teacher will not present the material completely organized for the pupils, but by means of questions and suggestions will lead them to do as much as possible of the organizing for themselves. One problem leads to another. One fact or phenomenon suggests the need for discovering another. The associations thus formed are likely to be frequent and vivid and to result in satisfaction; therefore they are more likely to be remembered.

(2) Unification by means of comprehensive principles.—The organization of the subject matter of physics should be progressive. The task of recalling and selecting from the accumulating mass of information those particular items that can be applied to a new problem becomes increasingly difficult. Fortunately the facts of physics can be unified by means of comprehensive principles. For example, most physics textbooks discuss the "three classes of levers," making much of the definitions and distinctions that may arise from the different relative positions of the fulcrum, the effort applied, and the resistance overcome. These distinctions serve no useful purpose. They are wholly traditional. In principle these levers are alike. Each is a case of the equality of opposing moments of force about a point; and so are others, such as the bent lever, wheel and axle, capstan, single fixed pulley, single movable pulley, rack and pinion, gear wheel, derrick, and the door on its hinges. Instead of a separate law for each, the one principle holds for all. It is their resemblances, not their differences, that should be emphasized. The ability to predict results by applying the one simple principle is the important ability to be gained. There will be no motion if the moment (measured by force multiplied by arm) that tends to rotate the device one way about an axis is equal to the moment that tends to rotate it in the opposite direction about the same axis. This

principle and the principles of the parallelogram of motions and the work principle are sufficient for the understanding of all cases involving the action of elementary machines. By a simple algebraic substitution any case coming under the principle of moments may be related to the principle of work. If to the work principle and that of the parallelogram of forces we add Newton's third law, we have the principles and definitions under which all the phenomena of the mechanics of solids included in the high school course may be grouped.

Nearly all the phenomena of fluids worth while for high-school students may be similarly grouped under the principle of Pascal, the principle of Archimedes, the principle that fluid work equals pressure multiplied by volume, and the principles already mentioned as summarizing the phenomena of solids. Also the principle of Archimedes may be shown to be only a type of application under the principle of Pascal. The principle of fluid work is not a new one, but only the definition that "work equals force multiplied by displacement," with the factors grouped in a different way, so that a pressure gauge may be used instead of a dynamometer for measuring the force. The relative compressibility of gases as compared with liquids necessitates the addition of Boyle's law as an interpretation of their behavior within certain limits under pressure. Otherwise their behavior is like that of liquids and can be summarized under the same laws.

After the phenomena of heat and electricity have been studied and similarly organized under a few comprehensive principles, it will be seen that the work principle is a special case, for solids and fluids, of the principle of the conservation of energy, and this principle may be taken as the great unifying generalization by means of which the phenomena in all the departments of physics are to be linked together.

The student thus brings all his knowledge of the subject into unified and harmonious relations by arranging small groups of phenomena under minor principles that describe them, then arranging these minor groups into major groups under major principles that describe all of them in a still broader way. Finally he is led to correlate all the major groups under such comprehensive laws and theories as the wave theory of sound, light, and electrical radiation, and the conservation of energy.

F. *Content.*—As has been said above under the caption of organization, the course, when it reaches the final stage of organization near the end of the year, should take the form of a body of facts and principles set forth in an orderly manner. The facts and laws of major importance should stand out clearly and should be grouped under the greater principles that give unity to the science. On the

other hand, when the facts or principles under a given topic are first introduced they should be organized about a series of problems or projects.

In the order of study, the facts and principles of mechanics are so fundamental to those of the other divisions, namely, heat, electricity, sound, and light, that the mechanical principles ought to come first. At least those most essential to the understanding of the others should do so, but there are many good reasons for deferring some of the most difficult mechanical principles till near the end of the course. For similar reasons molecular physics and certain portions of electricity and light may be deferred, thus giving the course some of the advantages of a so-called "spiral" method of treatment. Hence at first we should set up problems and projects mainly from the field of mechanics, then from heat, then from electricity and magentism, and finally from sound and light. There is, however, no good reason why facts or principles from one of these convenient groups should be excluded from every project until that group is reached. When working out projects in mechanics, for example, if electrical facts or light phenomena are needed for the solution of the problem, enough information about them to serve the purpose should be put within reach of the pupils, but these should be incidental at the time and should be reviewed and organized with the other electrical facts and principles when that main field is reached.

In choosing the projects through which the important principles are to be approached, and in solving which the important facts and laws are to be acquired, a leading criterion of selection should be the closeness of the project to the pupils' immediate interests and the immediate interests of the locality; but this criterion should not rule to the extent of circumscribing inquiry or curbing curiosity about the larger interests of the State, the Nation, and the world. The value of this criterion lies in the fact that the physical appliances and phenomena of the home, the farm, the near-by factory, the municipal water and electrical plants, are most easily perceived by the pupils to be of value to them and to the locality whose welfare is their own welfare and whose needs are their own needs.

Under *mechanics of solids*, the leading principles are those of gravity and center of mass, of work, energy, power, and efficiency relations, of equilibrium of moments of force, and of the composition and resolution of forces. These principles can be approached naturally and inductively through projects and problems connected with steelyards and balances, balancing toys, and "meccano" sets; sewing machines, washing machines, and wringers, and the simpler mechanical devices of daily household use; hand and machine tools used on the farm and in the shop; and the simpler mechanical

properties of bicycles and motor cycles, automobiles and farm tractors, wind mills, water wheels, and turbines, cream separators, motor boats, and sailboats.

Under *mechanics of fluids*, the leading principles are those of atmospheric and liquid pressure due to weight and depth, and to force externally applied, all involving the principles of Pascal and Archimedes, Boyle's law, and the application of the work principle to flowing liquids or gases under pressure. The problems selected for approaching these principles may come out of projects for milk testing, pumps, efficiency of water motors and windmills and hydraulic rams; the barometer and its relations to measuring heights and predicting weather changes; hydraulic presses, pneumatic drills, balloons, submarines, and diving apparatus.

In the domain of *heat*, the most important principles have to do with the factors of measuring heat (temperature change, specific heat, and mass) and the units in which heat is measured; changes from solid to liquid, vapor, or gas, and the reverse, together with the energy changes involved (heat of fusion and evaporation); the effects of such changes on climate; and the relations of heat to mechanical energy, including efficiency of heat engines and other heat appliances. Here the household heating and cooking apparatus, the school heating plant, the weather apparatus and maps, the steam and gas engines and turbines, and the smaller and more intimate facts and factors connected with housing and clothing may serve as starting points. These may lead to a genuine interest in experiments with thermometers, calorimeters, hygrometers, and other somewhat abstract but essential experiments of the laboratory.

Under *electricity* the important principles are numerous; but they center mostly about the production of electricity for power, light, and heat; its transmission from the place of production to the place of conversion; and the efficiencies of the apparatus used in producing, transferring, and converting it. Thus the study of electricity is largely a study of magnets, dynamos, primary and storage batteries, electrical currents and wiring, transformers, motors, bells, annunciators, telegraphs, telephones, electric lights, and electric heaters. Hence, the course should deal largely with these things, and with commercial measuring instruments, rather than with Daniell's cells, combinations of cells in series-multiple, Wheatstone bridges, electrostatic phenomena, vacuum tubes and the like, which make up so much of the traditional courses of the textbooks and syllabi.

Under *sound*, the greatest interest will naturally center around the simplest and most familiar musical instruments and the phonograph. Through these the properties of vibrating strings, rods, and air columns, of resonance, of simple and complex wave motion, and the basis of the chromatic and tempered scales can best be approached.

Under *light*, interest in the human eye and the photographic camera may lead easily toward projects that will result in an understanding of the rectilinear propagation of light, its reflection by mirrors, its refraction by prisms and lenses. The use of lenses for eyeglasses, magnifiers, microscopes, and telescopes would then follow as a natural subject of inquiry. Interest in color phenomena can easily be aroused by comparing the effects produced by mixing colors with the Maxwell disk, or the color top, with the very different effects obtained by mixing paints or dyes; and the whole subject of color can be interestingly reviewed and classified by careful examination of the facts of color photography and color-process printing. A natural introduction to the wave theory of light lies through the interference—fringes produced by a soap film. These may be compared with the "beats" produced as a manifestation of interference of sound waves when a pair of tuning forks or organ pipes of nearly the same pitch are sounded simultaneously; and also to the nodal points of a cord or wire that is vibrating in segments.

Throughout the course after the first ideas of work and energy have been introduced, the transferences of energy involved in physical phenomena should be made prominent by directing attention to the transfer from one body to another. When heat and work relations are taken up, the transformation of heat into mechanical work, and the reverse, should be emphasized in connection with many examples of transformation. As the students go on through the phenomena of electricity, sound, and light, the transference and transformation of energy should be brought out more and more strongly until the law of the conservation of energy has been grasped inductively and with such clearness as to serve as a great unifying principle in the organized scheme of the science at which the pupils are finally to arrive. The tendency of energy to run down through friction and other wastes into less available forms and conditions should also be brought out with increasing emphasis as the course progresses. Such exercises as tracing the energy of light and motion of a trolley car back to the coal or water power at the power house and thence back to the radiant energy from the sun will prove to be of great interest and value.

In conclusion, the motto "Not how much, but how well" should control the choice of subject matter. Quality rather than quantity of knowledge should be sought; and ability to control materials, forces, and ideas should be the aim, rather than the mere acquisition of facts and laws.

APPENDIX.

THE SCIENCE TEACHER.

The fundamental qualities that make for success in science teaching do not differ from those essential to success in teaching other subjects. In addition to the usually recognized values of good health, good spirits, poise, and reserve force, forceful personality and clear ideals of the purposes of democratic education, the science teacher should be an enthusiastic lover of science, and a believer in its great value, when rightly used, in the uplift of mankind. The science teacher should possess the power of leadership that comes from thorough knowledge of the things to be learned, the things to be done, and the reasons therefor. Those lacking in the power of leadership, which generates enthusiasm for the work and which makes arbitrary exactions and repressive disciplinary measures unnecessary, may learn it by practice and imitation from associates. As a leader, the science teacher must himself be willing to work hard. He must show an open mind on all questions and at all times in dealing with his pupils as well as in dealing with the facts of the subjects of study, and ideas. He should be genuinely interested in his pupils, their ambitions, their problems, and their success. He should be as ready to submit his teaching problems to experimental variation and systematic, controlled testing, as he is to appeal to experiment within the field of the science he is teaching.

Profound learning and research ability, although of great value, are not essentials for the high-school science teacher, but he must have sound scholarship and a large amount of common sense to know the proper relation of knowledge to human efficiency. The science teacher should neglect no opportunity to know well the sciences that he is teaching and to keep his knowledge as nearly as possible up to date, both as to facts and practical applications that touch closely on the things he is teaching. His knowledge should go beyond the mastery of the typical general college text in his subject, at least in some department or phase of it; and the more of such knowledge he had gained through actual laboratory practice, the better. It is highly desirable that the teacher's knowledge be extensive, covering many fields, as well as intensive in a few fields. All teachers of science should be able to draw fairly well, ready facility in the making of blackboard sketches and charts being especially desirable. They should also be skilled in the use of projection apparatus as well as the special demonstration and laboratory apparatus pertaining to their subjects. Science teachers should be fairly expert in the use of bench and machine tools since skill of this sort is of great ad-

vantage from time to time in teaching any of the sciences. Biology teachers, of course, should be skilled in the use of the microscope, in section cutting, and in the mounting of microscopic preparations for use in demonstrations. The making of photographs and lantern slides is another accomplishment of great value in all science teaching. The graphical method of presenting facts is well-nigh essential in the work of science teachers.

The better the science teacher's scholarship, the more effective is his teaching in most cases. He should have some knowledge of history, economics, and sociology, especially in those phases of these subjects in which science and the scientific method are shown to be related to human progress and welfare. Besides his major studies in the science or sciences which he teaches, he should have had at least a general college course in each one of these fields of science—biology, earth science, and physical science. A course in the teaching of each of the sciences in which he gives instruction is also very much to be desired.

Since psychology is fundamental in teaching, every science teacher ought to have at least one general course in psychology, with laboratory practice bearing especially on the learning processes, on the psychology of thinking, on individual differences, and on the practical relations of these to the art of teaching. Either as undergraduate or graduate work he should acquire a practical knowledge of intelligence tests and educational measurements and should have a course in secondary education, including the social and vocational aspects of high-school problems, the relations of science to the curriculum as a whole, and fundamentals of class management.

The professional spirit of the science teacher should prompt him to read, benefit from, and help support the special journals devoted to the interests and needs of teachers of the several high-school sciences, and to read at least occasionally such leading research journals in his special science as are likely to appeal to his students and to increase his own store of useful knowledge. As far as practicable, he should support and promote by membership and attendance at least one each of the local and national societies for the promotion of science and education. The science teacher should aim to be an exponent of science in his community and should respond willingly, whenever he can, to invitations to give illustrated popular lectures or talks to local gatherings or to the school on some of the interesting and socially important phases of his subject. Finally, if he can contribute something toward improving science teaching through individual or co-operative experimentation on content of the courses or devices and methods of teaching, he should be moved by professional zeal to give freely of his spare time and strength to this cause.

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